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SANITARY ENGINEERING.

A

SERIES OF LECTURES

GIVEN BEFORE THE

SCHOOL OF MILITARY ENGINEERING

AT CHATHAM, 1876.

LANE LIBRARY

BY

J. BAILEY DENTON, F.G.S., M. Inst., C.E.,

Author of

'SANITARY WORKS'; 'STORAGE OF WATER'; 'VILLAGE SANITARY ECONOMY';
'THE PROGRESS OF LAND DRAINAGE IN GREAT BRITAIN';
'THE FARM HOMESTEADS OF ENGLAND'; ETC.

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II. WATER.	V. DISPOSAL OF SEWAGE.
III. THE DWELLING.	

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THESE LECTURES

ON SANITARY ENGINEERING,

WHICH ESPECIALLY AIM AT BRINGING THE WORK OF THE ENGINEER

INTO CLOSER ALLIANCE WITH MEDICAL SCIENCE,

ARE DEDICATED WITH SINCERE RESPECT AND ADMIRATION

To the Memory of

EDMUND A. PARKES, M.D., F.R.S.,

PROFESSOR OF MILITARY HYGIENE IN THE ARMY MEDICAL SCHOOL; MEMBER OF THE GENERAL COUNCIL OF MILITARY EDUCATION,
ETC., ETC., ETC.

WHO, POSSESSING A PROFOUND KNOWLEDGE OF THE SUBJECT,

DEVOTED HIMSELF WITH UNTIRING ENERGY TO THE TEACHING OF HYGIENE IN

ITS MOST PRACTICAL FORM.

its ranks, and the guarantee for the fitness of its members." I thoroughly concur in this view, and hope that the time is not far distant when pupils in Sanitary Engineering will be able to present themselves for examination before a competent Board of Examiners authorized to grant diplomas of proficiency. At present no such capability exists, and the public are without any guarantee that local engineers and surveyors are able to appreciate the requirements of medical science, and to take advantage of those physical conditions, geological and meteorological, which, in every locality, govern largely the character of both Air and Water.

It will afford me the greatest satisfaction if in the following pages I have made it manifest that an Engineer should be a student in those branches of Science which bear upon Health before, in the exercise of his profession, he ventures to deal with these subtle elements.

J. BAILEY DENTON.

22, WHITEHALL PLACE, LONDON,
Christmas, 1876.

INDEX TO PLATES.

PLATE		OPPOSITE PAGE
I.	Section showing the Water Service to, and the Discharge of Liquid Refuse from, the Dwelling; Ventilation of Soil Pipe of Water-Closets, Sewer, and Traps; and Arrangement to prevent Damp in Basement Floors of Dwellings	56
II.	Plan showing the Discharge and Disposal of Liquid Refuse from a Country (isolated) Mansion ...	58
III.	Combined Arrangement of Private Communicating Sewers in Towns	58
IV.	Ventilating Cowls	108
V.	Water Supply Arrangement adopted at Gorhambury, Herts	132
VI.	Hydraulic Machines	134
VII.	Underground Tanks	142
VIII.	Domestic Filtration: Sketch showing the Relative Positions of Filters used for Roof Waters ...	144
IX.	Brick and Concrete Sewers	190
IX.[a]	River Crossing	198
IX.[b]	„ „	198
X.	Manholes and Ventilators for Sewers	200
XI.	„ „ „	200
XII.	Lampholes	200
XIII.	Flushing Arrangements of Sewers	202
XIV.	Gullies	210

		OPPOSITE PAGE.
XV.	Overflow Weir for Storm Water. Junction of Sewers (Curves)	210
XVI.	Liernur's Sewerage System (Pneumatic Subdivision)	294
XVII.	Sections showing Formation of Surface for Irrigation and Intermittent Filtration	314
XVIII.	Plan of Kendal Filtering Areas	332
XIX.	Sewage-distributing Arrangements at Kendal ...	332
XX.	Plan showing the Sewerage adopted at Abingdon and the Lands taken for the Cleansing of the Sewage	340

IN APPENDIX.

I.	Diagram showing the decline of Water under London, 1837 to 1850	374
II.	The Self-Acting Sewage Regulator	384
III.	Plan of Sewerage and Sewage Disposal at Eastwick Mansion and Village, near Letherhead ...	384

CONTENTS IN SECTIONS.

(For Index, see end.)

DIVISION I.

AIR.

I. Constituents of normal air.
II. Attainable standard of air.
III. Quantity of air respired by human beings.
IV. Oxygen.
V. Carbonic acid.
VI. Foreign matters polluting the air.
VII. Agencies counteracting the pollution of air.
VIII. Ground air.
IX. Malaria.
X. Carbonic acid as the measure of impurity of air.
XI. The duty of the engineer in relation to air.
XII. Dry and wet soils compared.
XIII. Wet soils injurious to the general health of districts, rural as well as urban.
XIV. Improved temperature of the atmosphere immediately incumbent on surfaces secured by the drainage of the subsoil.
XV. The maintenance of pure ground air, and superincumbent air, by the under-drainage of the soil surrounding and beneath dwellings, an object only inferior in importance to the removal of putrescible matters.

DIVISION II.

WATER.

XVI. Constituents of normal water.
XVII. Water, how polluted.
XVIII. Quantity of water required for all purposes.
XIX. Quantity and quality of water actually used in different towns in England.
XX. Yearly and monthly rainfall.
XXI. Infiltration of rain by absorbent soils in summer and winter.
XXII. Quantity of rain evaporated or lost from absorbent and non-absorbent surfaces.
XXIII. Quantity of rain thrown off pervious and impervious surfaces.
XXIV. Waters classified according to source.
XXV. Average composition of unpolluted waters.
XXVI. Classified results of the chemical analyses of waters.
XXVII. Wholesome waters.
XXVIII. Suspicious waters.
XXIX. Dangerous waters.
XXX. The engineer's view of the question.
XXXI. Of so-called "wholesome waters"—springs.
XXXII. Of so-called "wholesome waters"—deep wells.
XXXIII. Of so-called "wholesome waters"—waters collected from uncultivated surfaces.
XXXIV. From whence is a supply to be obtained in districts where neither spring waters, deep-well waters, nor waters from uncultivated lands are at command?
XXXV. Of so-called "suspicious waters"—waters collected from roofs and impervious surfaces.
XXXVI. Of so-called "suspicious waters"—the water of under-drainage.
XXXVII. Of so-called "suspicious waters"—water from cultivated surfaces.

XXXVIII. Of so-called "dangerous waters"—rivers, streams, and running waters.
XXXIX. Of so-called "dangerous waters"—shallow well waters.
XL. Hard and soft waters.
XLI. Concluding remarks:—Further investigation into the water question necessary.

DIVISION III.

THE DWELLING.

XLII. Definition of the term "the dwelling."
XLIII. Of the site.
XLIV. Drainage (in contradistinction to "sewerage") essential to a healthy site.
XLV. Definitions of the terms "drain" and "sewer."
XLVI. Of the capacities of different soils for the retention of water, and of the influence of wet soils on the sanitary condition of cellars and basements of dwellings.
XLVII. Capillary attraction and evaporation.
XLVIII. Mode of under-drainage required to dry the sites of dwellings.
XLIX. Concrete floors and areas essential to healthy basements, and damp-courses necessary in the walls of dwellings.
L. Dripping roofs.
LI. Definition of "sewage."
LII. The mode of disposing of the liquid refuse of dwellings must be determined before laying out the external sewers to collect and discharge it.
LIII. On present legal obligations in relation to the liquid refuse discharged from isolated dwellings.
LIV. Mechanical deposition and chemical precipitation inapplicable to the treatment of refuse liquid from isolated dwellings.

LV. The modes of sewage treatment available for isolated dwellings.
LVI. Means of collecting the liquid refuse of the dwelling, and of regulating its distribution on land.
LVII. Reasons why sub-irrigation may be dangerous.
LVIII. External sewerage of the dwelling:
(1) Construction of communicating sewers.
(2) Position or course.
(3) Inclination and velocity.
(4) Size.
(5) Liquid refuse from water-closets and urinals.
(6) Liquid refuse from sinks.
(7) Inspection shafts.
(8) Removal of grease and other solid matters deposited in trap-tanks or gullies.
(9) Gases from common sewers and cesspools.
LIX. The ventilating and flushing of the external sewers of the dwelling.
LX. Water-closets and their appliances, and the arrangements for ventilating them.
LXI. Sink appliances, and the arrangements for disconnecting the outlet pipes from the communicating sewer.
LXII. Scavenging and external dry closets.
LXIII. The ventilation of the dwelling.
LXIV. The water supply of the dwelling:
(1) Wells.
(2) Rain-water from roofs, &c.
(3) Surface water and under-drainage water.
LXV. Of different motive powers to raise water:
(1) Hand.
(2) Horse.
(3) Wind.
(4) Water.
(5) Steam.
LXVI. Pumps.
LXVII. Underground tanks for the storage of water.

LXVIII. Cisterns for the inner service of the dwelling.
LXIX. Domestic filtration.
LXX. Concluding remarks on the sanitation of the dwelling.

DIVISION IV.

THE TOWN AND VILLAGE.

LXXI. General observations on the duties of the engineer in relation to the sewerage of towns and villages.
LXXII. Surface waters, and their admission into or exclusion from sewers.
LXXIII. Road detritus, and its influence on the disposal of sewage.
LXXIV. Subsoil water, and its admission into or exclusion from sewers.
LXXV. Sewage proper, dependent in quantity on the following considerations:
(1) Population.
(2) Local and special trades, and
(3) Water supply.
LXXVI. The variation in discharge of sewage during the day—maximum and minimum.
LXXVII. The liquid sewage to be removed by sewers, distinguished from the solid refuse to be removed by the scavenger.
LXXVIII. General arrangement of sewers or the system of sewerage.
LXXIX. The mode of disposing of the sewage of towns and villages to be determined before fixing the main outfall or intercepting sewers.
LXXX. On the classification of towns and villages, and the appropriate disposal of their sewage according to the nature of the outfall:
(1) Seaboard towns
(2) Towns on tidal waters.
(3) Inland towns.
(4) Villages and hamlets—their special treatment.

LXXXI. Main outfall and intercepting sewers.
LXXXII. Sizes and velocities required to render sewers self-cleansing.
LXXXIII. Circular and egg-shaped sewers compared.
LXXXIV. Construction and materials of sewers:
(1) Brick sewers.
(2) Pipe sewers.
(3) Concrete sewers.
(4) River crossings and sewer deflections.
LXXXV. Sewer appliances adopted by different engineers:
(1) Manholes and lampholes.
(2) Flushing arrangements and penstocks.
(3) Gullies.
(4) Storm overflows, and tidal or outlet valves.
LXXXVI. Sewer ventilation.
LXXXVII. Scavenging of towns and villages.
LXXXVIII. On the water service of towns and villages, with remarks on the constant system of supply.
LXXXIX. Concluding remarks on the sanitation of towns and villages.

DIVISION V.

THE TREATMENT AND DISPOSAL OF THE SEWAGE OF TOWNS AND VILLAGES.

XC. Prefatory observations on sewage disposal.
XCI. Character of sewage discharged by sewers of towns and districts of different characters.
XCII. The value of sewage.
XCIII. The solid matters contained in sewage.
XCIV. Of "sludge."
XCV. The clarification of liquid sewage by subsidence or chemical precipitation in tanks.

(1) The A B C process (Native Guano Co.)
(2) The phosphate of alumina process (Phosphate Sewage Co.)
(3) The sulphate of alumina process (General Sewage and Manure Co.)
(4) Whitthread's process.
(5) Messrs. Weare and Co.'s process.
(6) Hille's process and other processes.
(7) The burning of the combustible constituents of sewage in the manufacture of cement and limes (Scott's Sewage Co.)
(8) Liernur's system of treatment.

XCVI. The advantage of retaining the sludge in the liquid sewage when it is applied to land.

XCVII. Circumstances under which the special treatment or riddance of sludge may be necessary.

XCVIII. The temperature of sewage.

XCIX. Land the purifier of liquid sewage, and liquid sewage the fertilizer of land.

C. Wide surface irrigation :
(1) Suitable and unsuitable soils.
(2) Under-drainage and surface preparation.
(3) Delivering conduits, tanks, sluice chambers, carriers, and distributing channels.
(4) The catch-water system of distribution.
(5) The pane-and-gutter system of distribution.
(6) The bed system of distribution.

CI. Intermittent downward filtration :
(1) Suitable and unsuitable soils.
(2) Under-drainage.
(3) Surface preparation and formation.
(4) Delivering conduits, tanks, sluice chambers, carriers, and distributing channels.
(5) The Merthyr works described.
(6) The Kendal and other works described.
(7) Cleansing of trade refuse.

(8) General remarks with reference to works in progress in different parts of the country in which intermittent downward filtration is adopted wholly or partially.

CII. Combination of intermittent downward filtration with wide surface irrigation essential alike to the profitable utilization of the sewage, and the constant purification of the effluent.

CIII. Combined works for interception and disposal of sewage in crowded valleys frequently advantageous.

CIV. On the sanitary condition of localities in proximity to land upon which sewage is applied.

CV. Concluding remarks.

DIVISION I.

AIR.

I.—Constituents of Normal Air. Air in its normal condition consists of about four-fifths, by volume, of nitrogen,* and one-fifth of oxygen,† mixed with a very small proportion of carbonic acid.‡ Speaking more precisely, I should state that it has been ascertained by the valuable researches of Dr. Angus Smith that very pure air contains not less than 20·99 per cent. of oxygen, and not more than ·03 of carbonic acid.

II.—Attainable Standard of Air. According to the same authority a favorable, though not the purest, specimen of air may be taken to contain by weight, of oxygen 20·96, of nitrogen 79·00, and of carbonic acid ·04 per cent., with a varying quantity of watery vapour.

We may take these figures as representing a fair attainable standard of pure air, and may therefore conclude that directly these proportions are altered by an increase of carbonic acid, and a mixture of other foreign matters, involving a reduction of oxygen, the quality is lowered.

Air, in fact, "with a very small loss of oxygen, is perceptibly deteriorated if the place of the oxygen is occupied with carbonic acid and exhalations from the person, although we are not able to say how far this is the case when carbonic acid alone is substituted for this small amount of oxygen."—*Angus Smith.*

* Nitrogen is a gas devoid of either color, taste, or smell. It acts chiefly in diluting the oxygen. In pure nitrogen animals cease to live. Its weight is a thirty-sixth part less than common air.

† Oxygen too is without either taste or smell. Of all elements it is the most abundant, forming eight-ninths, by weight, of the water, one-fifth, by volume, of the air, and one-third of the solid matter of the globe. Though absolutely necessary to the life of man and animals, it is too strong to be breathed for any length of time in a pure condition without fatal results. Oxygen is one-ninth part heavier than common air.

‡ Carbonic acid is a gas which, unlike oxygen and nitrogen, possesses a perceptibly sour taste. It is described as a compound of carbon and oxygen, in the proportion of three parts, by weight, of carbon, and eight of oxygen, and is the result of the combustion of carbon. It was called "fixed air" by our older chemists, and to coal miners and well sinkers it is known as "choke damp." For plants it is essential, being the source from which the carbon of their tissues is derived.

The diminution of oxygen is very sensibly felt directly its quantity is reduced as low as 20·75 per cent.

III.—Quantity of Air respired by Human Beings. To understand to what extent a loss of oxygen and an excess of carbonic acid mixed with deleterious foreign substances may affect the health of human beings, it should be understood that Professor Huxley states that in respiration about 350 cubic feet of air pass through the lungs of each individual per diem. "In passing through the lungs the air would lose from 4 to 6 per cent. of its volume of oxygen, and gain 4 to 5 per cent. of carbonic acid.

"During 24 hours there would be consumed about 10,000 grains oxygen, and produced about 12,000 grains carbonic acid, corresponding to 3,300 grains carbon. During the same time about 5,000 grains, or 9 ozs. of water, would be exhaled by the lungs.

"In 24 hours such a body would vitiate 1,750 cubic feet of pure air to the extent of 1 per cent., or 17,500 cubic feet of pure air to the extent of 1 per 1,000. Taking the amount of carbonic acid in the atmosphere at three parts, and in expired air at 470 parts in 10,000, such a body would require a supply per diem of more than 23,000 cubic feet of ordinary air, in order that the surrounding atmosphere might not contain more than 1 per 1,000 of carbonic acid (when air is vitiated from animal sources with carbonic acid to more than 1 per 1,000, the concomitant impurities become appreciable to the nose). A man of the weight mentioned (11 stone) ought therefore, to have at least 800 cubic feet of well ventilated space."

Upon this subject Dr. de Chaumont says that each adult consumes in food from 3,500 to 4,000 grains of carbon in 24 hours, *i.e.*, from eight to nine ounces, and he exhales, as carbonic acid, about the same quantity, which is equal to 17 cubic feet of the gas, to vitiate the atmosphere. In addition to this gas a quantity of watery vapour is given off from the person, varying according to circumstances from six to 27 ounces; and Dr. de Chaumont adds, "An assemblage of 2,000 persons will give off in two hours (in vapour) 17 gallons of water, and nearly as much carbon as would be extracted from a cwt. of coals."

Dr. Parkes says in his "Practical Hygiene" that "an adult man in ordinary work gives off, in 24 hours, from 12 to 16 cubic feet of carbonic acid gas, and also emits an undetermined quantity of carbonic acid gas by the skin."

IV.—Of Oxygen. "The mean quantity of oxygen in the extremely pure air at the *sea shore* and on the *heaths* of Scotland is

represented to be 20·999 per cent., while the mean of the *low marshy* places (Scotland) is 20·922."—*Angus Smith* From these figures it will be seen that the better air of the sea shore and the heaths contains ·039 per cent. of oxygen *above* that expressed in the standard of purity which I have quoted, while the worse air of the marshes contains ·038 per cent. below it. It will be observed, however, that although the sanitary conditions of the two are very different, that difference is limited to ·077 of one part in 100 parts, or, in other words, to rather less than $7\frac{3}{4}$ parts in 10,000 parts.

To show how the loss of a small portion of oxygen indicates a very great reduction of salubrity, I have collected from various authorities the quantities of oxygen which have been found to exist in different places under different conditions.

OXYGEN—*Standard*, 20·96 *per cent.*

	Oxygen per cent.	More or less than attainable standard per cent.
Front of Glasgow Exchange	20·895	... ·065 less.
Kirk Street, Glasgow	20·875	... ·085 „
Regent Street, London, November ...	20·865	... ·095 „
Hackney „ „	20·835	... ·125 „
Chelsea „ „	20·810	... ·150 „
Middle of Hyde Park „	21·005	... ·045 more.
Metropolitan Railway, underground ...	20·600	... ·360 less.
Sitting Room	20·890	... ·070 „
Small Room, petroleum lamp burning ...	20·840	... ·120 „
Pit of Theatre	20·740	... ·220 „
Gallery of Theatre	20·630	... ·330 „

V.—OF CARBONIC ACID. An increase of a very minute proportion of carbonic acid in the air, with a corresponding loss of oxygen is quickly perceptible to the senses, although the difference (if accurately ascertained by analysis) will be indicated by figures in the second and third place of decimals.

" Some people will probably enquire why we should give so much attention to such minute quantities—between 20·980 and 20·999—thinking these small differences can in no way affect us. A little more or less oxygen might not affect us; but supposing its place occupied by hurtful matter we must not *look on the amount as too small.* Subtracting 0·980 from 0·999 we have a difference of 190 in a million. In a gallon of water there are 70,000 grains: let us put into it an impurity at the rate of 190 in 1,000,000; it amounts to 13·3 grains in a gallon, or 0·19 grammes in a litre. This amount

would be considered enormous if it consisted of putrifying matter, or any organic matter usually found in waters; but we drink only a comparatively small quantity of water, and the whole 13 grains would not be swallowed in a day, whereas we take into our lungs from 1,000 to 2,000 gallons of air daily. The detection of impurities in the air is therefore of the utmost importance, and it is only by the finest methods that they can be ascertained in small quantities of air, even when present in such quantity as to prove deleterious to health."—*Angus Smith "Air and Rain."*

It is needless to point out that the amount of carbonic acid associated with contaminating foreign matters will necessarily be found to increase, and the amount of oxygen to decrease in a greater degree in " confined spaces " than in the open country. I am not at this moment treating of the air of rooms within dwellings with which the architect has more to do than the engineer, but of the outside atmosphere upon which the inmates of all dwellings depend as a source from which to dilute the inner air when it has become polluted by the respiration and combustion constantly going on in all human habitations, mills, factories, &c., and in the stables, out-buildings, &c., occupied by domestic animals. With this outside atmosphere the engineer has everything to do.

That we may, however, appreciate the differences between the attainable standard of pure air, which I have quoted, and the fairly good atmosphere of open spaces, and compare both with the air of confined inner spaces, I will give you the quantity of carbonic acid as it is found to exist in the air of a variety of places.

CARBONIC ACID—*Standard, ·040 per cent.*

	Per cent.	More or less than standard per cent.
OPEN SPACES (MANCHESTER) :—		
Fields in Green Leys	·0383	·0017 less.
Old Trafford	·0432	·0032 more.
Do.	·0291	·0109 less.
Church Yard, All Saints	·0323	·0077 „
Smithfield Market	·0446	·0046 more.
CONFINED SPACES (MANCHESTER) :—		
Factory Mills	·2830	·2430 more.
School Room	·0970	·0570 „
Theatre Royal (Pit)	·2734	·2334 „
OPEN SPACES (LONDON) :—		
Cheapside	·0352	·0048 less.
Lower Thames Street	·0428	·0028 more.

CARBONIC ACID—*Standard* ·040 *per cent.*

	Per cent.	More or less than standard per cent.
OPEN SPACES (LONDON):—		
Top of Monument	·0398	·0002 less.
Hyde Park	·0334	·0066 ,,
Oxford Street	·0344	·0056 ,,
Regent's Park	·0304	·0096 ,,
CONFINED SPACES (LONDON):—		
Chancery Court (shut)	·193	·1530 more.
Do. (open)	·0507	·0107 ,,
Strand Theatre (gallery, 10 p.m.)	·101	·0610 ,,
Surrey Theatre (boxes, 12 p.m.)	·218	·1780 ,,
Olympic Theatre (11.55 p.m.)	·1014	·0614 ,,
Standard Theatre (pit, 11 p.m.)	·320	·2800 ,,
Metropolitan Railway, between Gower Street and King's Cross	·338	·2980 ,,
OPEN SPACES (FOREIGN):—		
Lake of Geneva	·0439	·0039 ,,
Chambeisy	·0460	·0060 ,,
Munich	·0500	·0100 ,,

A very interesting table is given by Dr. Parkes in his *Practical Hygiene*, from experiments made by Dr. de Chaumont, showing the difference between external air and that prevailing at the same time in certain Barracks and Civil and Military Hospitals.

AMOUNT OF CARBONIC ACID IN ONE HUNDRED VOLUMES OF AIR.

	Carbonic acid, external air.	Carbonic acid, internal air.		Mean respiratory impurity.
		Largest amount found.	Mean amount.	
BARRACKS:—				
Gosport New Barracks	·043	·184	·064	·021
Anglesey Barracks	·039	·197	·140	·101
Aldershot	·044	·140	·049	—
Chelsea	·047	·117	·071	·024
The Tower of London	·042	·173	·133	·090
Fort Elson (casemate)	·042	·187	·120	·078
Fort Brockhurst (do.)	·042	·102	·083	·041
MILITARY AND CIVIL HOSPITALS:—				
Portsmouth Garrison Hospital	·030	·205	·097	·067
Do. Civil Infirmary	·032	·130	·092	·060
Herbert Hospital	·042	·073	·047	·005
Hilsea Hospital	·040	·074	·057	·017

AMOUNT OF CARBONIC ACID IN ONE HUNDRED VOLUMES OF AIR.

	Carbonic acid, external air.	Carbonic acid, internal air.		Mean respiratory impurity.
		Largest amount found.	Mean amount.	
MILITARY AND CIVIL PRISONS :—				
Aldershot Military Prison Cells	·040	·348	·165	·124
Gosport do. do. Cells	·055	·234	·133	·078
Chatham Convict do. Cells	·045	·309	·169	·124
Pentonville Prison Cells, Jebbs' system ...	—	·192	·098	—

" The last column of this table shows the condition of the ventilation as measured by the carbonic acid. It is very satisfactory in the new barracks (Gosport and Chelsea), but is much less so in the old barracks and casemates. The Herbert and Hilsea Military Hospitals show excellent ventilation, while the old fashioned Portsmouth Garrison Hospital is very bad in this respect. The prison cells show in all cases a very high degree of respiratory impurity, and this must be one of the depressing influences of long cell confinement. The amount of carbonic acid is often much greater than in the above instances."

In a boys' school with 67 boys and 4,640 cubic feet (=69 cubic feet per head) Roscoe found 3·1 parts of CO_2 per 1,000 (·31 per cent).

In a girls' school room (70 girls and 10,400 cubic feet, or 150 cubic feet per head) Pettenkofer found no less than 7·230 parts per 1,000 (·723 per cent.).

In a horse stable at the Ecole Militaire the amount was 7 per 1,000 (·7 per cent.).

VI.—POLLUTING FOREIGN MATTERS. Excluding from consideration the watery vapour that exists to the extent of 40 per cent. of saturation in the driest, to complete saturation in the dampest air, and may therefore be considered, though varying in quantity, to be almost a normal constituent, the foreign matters to which I have before referred, and which impart to the air those impurities which vitiate its normal condition, are (1), the gases which rise in the shape of ammonia from organic matters, as decay and putrefaction take place; (2), those acids or gases which emanate from inorganic matters in their natural state, or when brought into use by man; and (3), mechanically suspended impurities, *i.e.*, those substances consisting of particles of the soil or dust, the pollen and seeds of plants, decaying tissue, &c., which float in the air are of minute size, and

may be partially seen by the eye in any ray of light. It is these suspended and floating particles that have been shown by Professor Tyndall to reflect and scatter light itself.

The amount of watery vapour which in this country is considered most congenial to health is from 65 to 75 per cent. of saturation.

VII. — Counteracting Agencies. These deteriorating foreign materials, however, are counterbalanced by natural agencies,—winds and currents, diffusion, oxidation, and the very powerful influences of vegetation. Beyond these there is the action of that substance known as *ozone*. This valuable element is described by Dr. de Chaumont as a modification of oxygen in which more than the usual number of atoms are brought together. "Ozone," he says, "oxidizes (burns, in fact) organic matter with great rapidity, much more rapidly, in fact, than ordinary oxygen. In this way it may be considered the great scavenger of the air." Dr. Cornelius Fox describes the sources of ozone to be "the oxidation of metals, the decomposition of rocks, the germination of seeds, the growth of plants, the falling of dew, rain, hail, and snow; the collision between air currents of different degrees of humidity proceeding from opposite quarters with one another, or with the earth; the evaporation which is continually proceeding from saline fluids, such as oceans, seas and lakes; the dashing and splashing, the smashing and crashing of the restless waves on the rocky coast;" which, he says, "are all concerned in the simultaneous development of electricity and ozone." This description expresses not only the sources of ozone, but includes, in fact, the several agencies which counteract air pollution.

VIII.—Ground Air. All air existing in and emanating from soil is rich in carbonic acid associated with effluvia and organic gases, governed in quantity by the amount of animal and vegetable substances existing in the soil. Sulphuretted hydrogen is found under special circumstances. These emanations are the result, I presume, of the very remarkable disinfecting powers of soil which Dr. Angus Smith says will purify by oxidizing "sulphuretted hydrogen water, or its compound with ammonia, on a few inches of soil in a few minutes." ("*Air and Rain.*") They will continue to be given off from the surface so long as there exists beneath any organic matter to be oxidized.

Soils have different powers of decomposing organic substances without lessening the amount of carbonic acid gas evolved. Some soils, in fact, are purified by the air existing in them at the expense

of the air incumbent upon them. Fleck, of Dresden, in his experiments on ground air, found that with an increase of carbonic acid there was a corresponding decrease of oxygen, and that the rate of decomposition is very much slower in clay (as every one would expect) than in sands and gravels, while the amount of carbonic acid given off by the slower decomposition taking place in clays was very much greater than from the more rapid decomposition in sands and gravels, though the latter was effected in half the time.

Some recent experiments of Professor Ripley Nichols, of the Massachusetts Institute of Technology, however, afford some satisfaction upon this head. He (Professor Nichols) examined the air from soils saturated with semi-liquid sewage (May 13th, 1875), the experiments being so carefully arranged as to allow of specimens of air being taken for analysis from different depths and at different times and dates. In his *Observations* describing these experiments, Professor Nichols says :—" On the 5th June (1875) the examination of the air in the soil and at the surface of the ground was begun, and examinations have been made at intervals until the present date (Nov. 10th). The general results of the examinations may be summed up as follows : The gaseous products of decay which might be expected to be produced from such a mixture of animal and vegetable matter are sulphuretted hydrogen, ammonia, carbonic acid, and marsh gas ; the first, sulphuretted hydrogen, was not detected even in the air taken fourteen inches from the surface of the ground, *i.e.*, less than six inches from the top of the decaying matter ; ammonia was not found in any appreciable amount ; there seemed to be a small amount of marsh gas formed, and of carbonic acid a very large quantity was produced. The amount of carbonic acid was greatest in the neighbourhood of the decaying matter, and decreased in amount towards the surface of the ground. The maximum amount was observed during July and August. Observations made since the 1st of October show that the amount is steadily decreasing, Also, since the 1st of October, marsh gas has not been observed in the ground atmosphere." * * * " More complete examinations of the air were made with the following results :—

Tube H (14 inches from the surface),

	June 21.	June 26.	Oct. 16.	Nov. 10.
Oxygen	14·76	13·49	15·39	16·95
Carbonic acid	11·51	13·28	6·28	2·82
Nitrogen	73·73	73·23	78·44	79·23

The counteracting effect of diffusion in the atmosphere was shown in the case to which these figures apply, by the fact that at a few feet from the ground no excess of carbonic acid could be detected."

In a previous publication Professor Nichols recorded a somewhat extended series of determinations, made in 1874 in a deep bed of gravel. He says that the depth of the gravel to the river mud beneath was 19 feet, and that a portion of the mud was brought up for examination. "It was found (after being dried at 212° F) to lose 4 per cent. on ignition, and consisted mainly of sand containing some fragments of shells. It contained traces of ammonia and some nitrogenous organic matter, but no sulphuretted hydrogen or sulphides. Air was drawn through a glass tube from a depth of 10 feet, and was found to contain some ammonia, but no sulphuretted hydrogen. Two pipes were sunk in the manner described, so as to draw the air from a depth of 6 feet and 10 feet respectively." The results of the examination are embodied in the following table :—

CARBONIC ACID EXPRESSED IN PARTS PER 1,000.

Date.	Amount of Carbonic Acid at a depth of		Distance from surface of ground to surface of ground water.		Remarks.
	10 ft.	6 ft.			
1874.			ft.	in.	
May 5	—	—	10	3	The height of the ground water was measured at a point some 150 feet distant from the point at which the air was taken. It is however sufficiently exact for the present purpose, as there is probably little difference in the height at the two points.
,, 8	—	—	10	6	
,, 11	—	—	10	9	
,, 12	—	4·17			
,, 13	—	4·20			
,, 14	—	4·01	More than		
,, 16	—	5·21	10	9	
,, 18	—	5·98			
,, 21	4·31	6·40			Air of 10-foot pipe tested for sulphuretted hydrogen with negative results.
,, 22	4·74	6·33	10	8	
,, 27	6·88	7·24	10	8	A heavy rain, May 25th.
June 9	10·50	9·64			
,, 17	15·50	13·40			
,, 25	20·26	14·20	More than		
July 4	—	17·59	10	9	Dry weather.
,, 13	16·37	18·37			Heavy rain, July 12th.
,, 25	20·26	20·20			
Aug. 10	20·60	—	10	8½	
,, 20	21·21	20·71	—		Air of 10-foot pipe tested for sulphuretted hydrogen with negative results.
Sep. 5	—	16·97	—		
,, 15	12·85	17·07	—		
,, 26	14·73	6·98	—		
Oct. 6	10·00	6·74	—		
Nov. 5	—	8·95	—		
,, 6	15·32	9·52	11	10	
,, 10	15·31	9·19	11	10	
,, 14	13·13	7·07	12	0	
,, 18	12·59	6·88	11	11	
,, 21	11·72	5·89	11	11	
,, 23	—	4·33	11	11	Snow and rain the night previous.
,, 24	8·08	—	11	9	Very windy.
Dec. 8	8·06	4·11	11	10	Rain, December 7th.
,, 14	7·92	3·49	—		Rainy.
,, 15	6·39	3·28	11	11	Very cold.
,, 29	5·10	3·23	11	11	Very cold.
1875.					
Jan. 5	2·12	2·45	12	½	A light snow or sleet fell January 2nd, and covered the surface of the ground with a continuous icy coating which had not melted January 5th.

The ground in proximity to every dwelling being always traversed to some extent by one or more sewers (to discharge the sewage of the dwelling), it is desirable that the nature of "sewer air"* should be understood, for if it escapes from sewers that are not air-tight into the ground it adds very much to the defilement of the soil, and causes a greatly increased evolution of carbonic acid from the surface, thus creating a condition of atmosphere partaking of a malarious character. In most cases sewer air consists of a "variable amount of sulphuretted hydrogen, ammonium sulphide, nitrogen, carbonic acid, and carburetted hydrogen, in addition to fœtid organic matters. These organic matters are in large amount." "Marsh gas is found in sewers when oxidation is impeded, and sulphuretted hydrogen and ammonium sulphide are liberated." "The organic vapour is carbo-ammoniacal."—*Parkes.*

It appears manifest to me that the escape of these constituents into the ground surrounding dwellings must be injurious, for the gases evolved in sewers are frequently fired by the candles of sewer-men, and in a case in my own practice where an examination was being made of the condition of a sewer running *under* a large establishment, in which there were at the time 250 inmates, the confined gas took fire from a workman's candle and passed through the entire length of a long basement. Little attention is at present given to matters like this, though they cannot fail to show that sewers with air-tight joints are desirable near dwellings. If they are air-tight they are necessarily water-tight, and then the sewage itself, with its 72 parts of dissolved solids in 100,000 parts, will not escape into the soil surrounding the sewer, to render it "excrement sodden," and gravitate by soakage to the foundations and basements.

IX.—Malaria. To arrive at the precise nature of miasma many experiments have been made. One was carried out in Italy by collecting the moisture of the air in the immediate proximity of certain marshes known to be subject to malaria, as it was deposited on the surfaces of bottles containing ice. This moisture when condensed was found to contain nitrogenous substances, which putrified, and soon exhibited animalculæ.

* The following tabular statement of the condition of the air taken from the sewers mentioned, is taken from the "*Pharmaceutical Journal*," October 11, 1873:—

		PERCENTAGE.			
		Nitrogen.	Oxygen.	Carb. Acid.	Sul. Hyd.
Sunderland ...	1871	81·1	18·4	0·5	Traces.
Ditto ...	1873	80·35	19·37	0·23	None.
London ...	1858	79·96	19·51	...	Traces.
Paris ...	1858	78·86	17·93	2·	0·92.

I do not know if any like analysis has been made of the moisture evaporated from the back yards of houses and cottages in some of the filthy towns and villages which exist in this country, but I can well understand that one great cause of disease in Great Britain, in spite of its advantages of climate, is the amount of evaporation which takes place in association with organic emanations, and that it does not require the heat of a southern climate to produce an atmospheric condition, differing only in degree from the malaria which we have been accustomed to associate only with distant and hot countries.

That heat has an extraordinary influence in promoting malaria wherever organic substances are collected upon a wet soil, I can support by my own investigations in Italy. I found—in the autumn of 1864 when examining the sea-board marshes between Civita Vecchia and Pœstum for the purpose of ascertaining their capability of growing cotton—that it required neither warning nor guide to enable me to identify infected districts, nor that any one organ or sense alone detected the obnoxious atmosphere. The senses generally became affected. In every instance of infected air with which I then became cognizant the subsoil water was within a little depth of the surface, and the quantity of decomposable organic matter was very large.

Such a state of things an English agriculturist would quickly and radically alter—as unprofitable in cultivation, and injurious to vegetation—by *under-drainage*. The Italians, however, knowing that the difference between high and low tide in the Mediterranean Sea is practically nothing, and that therefore there was no capability of tidal discharge, instead of raising the injurious waters by steam, as is done in this country, in Holland, and other countries, and discharging them above sea level, adopt the raven scheme of raising the land itself with débris from the Appenines by warping—a process called "bonification"—which has the effect of covering the surface with solid material, and of leaving the soil below still saturated with water without eradicating malaria.

X.—On Carbonic Acid as the measure of Impurity of Air. If the exact measure of impurity of air was simply that expressed by the increased amount of carbonic acid, or the reduced amount of oxygen which it contains, it would not be long before the engineer, as well as the medical officer, could ascertain the exact condition of the air of any locality. But it is not exactly so. Though the increased amount of carbonic acid is some guide to the extent of impurity existing in the air, it gives no clue to the quality of that impurity, nor can we accept as a rule the assumption that as the

quantity of carbonic acid increases so will be the reduction of oxygen.

Dr. Parkes, however, gives the following reasons for taking carbonic acid as the index of impurity: "The carbonic acid which an adult man adds to the extent of about $\frac{6}{10}$ths of a cubic foot in an hour is not within certain limits an important impurity, but as it is practically in a constant ratio with the more important organic matter of respiration, and as it is readily determined, it is taken as a convenient index to the amount of the other impurities.

"Taking the carbonic acid as the measure of the impurity of the air vitiated by respiration (and by respiration alone), we have to ask what is to be considered the standard of purity of air in dwelling rooms? We cannot demand that the air of an inhabited room shall be absolutely as pure as the outside air; for nothing short of breathing in the open air can ensure perfect purity at every respiration. In every dwelling room there will be some impurity of air." * * "It appears from experiments made by Dr. de Chaumont and myself, that the organic impurity of the air is not perceptible to the senses until the carbonic acid (*i.e.*, the initial and the respiratory carbonic acid) rises to the ratio of ·6 per 1,000 volumes (·06 per cent.), or ·0006 in each cubic foot."

"Pettenkofer has now adopted the limit of ·7 measures of CO_2, and Degen ·66 measures per 1,000, as the amount when the organic matter simultaneously present becomes perceptible. I would propose then to adopt the amount of ·6 cubic feet per 1,000 volumes (·06 per cent.) of total carbonic acid (initial and respiratory) as the limit of impurity. I admit that I am not able to show by direct evidence that impurity, indicated by ·7 or ·8, or even one volume of carbonic acid per 1,000, and organic impurities in proportion, is injurious to health. We possess no means of testing the effects of such small quantities. Such a standard must be adopted, first, on the general evidence that large aërial impurities are decidedly hurtful, and that smaller amounts may be presumed to be so in proportion, although we cannot measure the action; and, secondly, on the fact that we have an obvious and simple measure in the effect produced on the senses, which gives us a practical line of demarcation we could not otherwise obtain."

But to ascertain the amount of carbonic acid in the air seems to the uninitiated not to be a very easy matter, even in the hands of chemists. To the engineer who is not acquainted with chemistry it is practically beyond reach, although Dr. Angus Smith (*Air and Rain*, p. 192), details several means of effecting what he terms "simple" tests, and which he calls the minimetric method (see

Appendix A). The method adopted by Pettenkofer is also said to be easy of performance. The explanation of that method (given by Dr. Parkes) will be found in the Appendix (see B). It is to be hoped that some self-recording instrument to correspond with the barometer, the thermometer, and the hygrometer, may yet be invented by which the amount of carbonic acid in the air may be read off with simplicity.

XI.—The Duty of the Engineer in Relation to Air. It will be asked,—In what way can the sanitary engineer govern the condition of the air? I will do my best to answer the question.

By appropriate drainage of the ground forming the sites of dwellings, and of towns and villages (which are the congregation of dwellings) not only may the soil be made absorbent of liquid-filth, and capable by its aëration of oxidizing the nitrogenous matter which it absorbs, but by the adoption of adequate depth of drains the uprising of polluted liquid in the soil, and the consequent evolution of pernicious gases rising by evaporation into the air, and permeating the basements of dwellings, may be prevented. Moreover, I believe that as these points are established and drainage is adopted we shall go further and acknowledge a sensibly improved temperature of the air as an unmistakeable consequence of under-draining the sites of dwellings. If I am right in these views, one of the first duties of the engineer, when carrying out sanitary works, is to render the ground upon which any dwellings stand free from subsoil water to within a recognised depth of their foundations. It is only by such means that the ground is made capable of supporting the incumbent outer air in such a state of purity (as indicated by the amount of carbonic acid it contains) that it shall always be available for the dilution of the air within dwellings.

Perhaps the most fruitful source of impurity of air in dwellings is the damp condition of the ground immediately beneath and adjacent to them, which often becomes saturated with liquid filth by the too frequent practice of throwing the slops of the dwelling upon the surface of yards and gardens, or—what produces nearly as bad a condition—by heaping upon it solid house refuse of all sorts to be washed into the soil by the rainfall, and to give off effluvia from their accumulated heaps, or to spread their minute particles in the air and be taken into the lungs by respiration.

It is when such a state of things exists that malaria may be said to surround the dwelling, and render the outer air unfit for the dilution of the inner air. The malaria which prevails in certain countries can hardly be dissimilar in some respects to the air which exists over

"excrement-sodden" ground and refuse-covered yards, though the effect may be worse in a hot than in a moderately cool climate like our own. In both, the absence of under-drainage is the primary cause of evil, and, in both, a soil aërated by under-drainage would to a certain extent oxidize the organic matters it contains, and greatly prevent the generation of miasma.

XII.—Dry and Wet Subsoils compared. In order to ascertain the influence of a drained soil upon human health, as indicated by the rate of mortality from consumption, we should examine the effect of a wet atmosphere and compare it with that of a dry one. It is found that the number of deaths from consumption in towns which are naturally dry is so very much less than in towns which exist on a wet soil, that it is now believed by many that this disease is the offspring of defective drainage.

Dr. Buchanan, of the Local Government Board, has very carefully investigated this subject, and reported upon it to the Medical Officer of that Board (Mr. Simon) who states in his general report (March 31st, 1868), that the investigation "confirms beyond all possibility of question the conclusions previously suggested, that dampness of soil is an important cause of phthisis to the population living upon the soil." Dr. Haviland, of Northampton, Dr. Seaton, of Nottingham, Dr. Fenton, of Coventry, and many other medical authorities, all support, in a greater or less degree, the conclusions come to by Dr. Buchanan; but, perhaps, there is no more conclusive proof of the injurious effect of dampness of soil upon the health of a locality than that afforded in this district of Rochester, of which Dr. Sladen Knight says, "the annual death-rate of the Rochester Urban Sanitary District, calculated on the mortality of the three months ending 30th Sept. last (1875), exclusive of deaths occurring in hospitals, was 15·910 per 1,000, whilst the annual death-rate of the drier portion of the city within the Medway district, *i.e.*, the part situate on the east side of Rochester bridge, was but 12·494, and in the North Aylesford district, on the west side of the bridge, consisting principally of Strood, the greater portion of which is built on low-lying land, and is frequently inundated by the tide, the death-rate was 23·800. This wide difference in the annual death-rate in the two divisions is, I own, more conspicuous in the last quarter than in any previous returns, although in every instance, I believe, the comparison has been against the North Aylesford or Strood division."

The importance of a dry soil as the site of human habitations is well authenticated by the report of Dr. Bowditch addressed to the Medical Society of Massachusetts, U.S.A., which runs thus:—"Medical

opinion as deduced from the written statements of resident physicians in 183 towns tends strongly to prove—though, perhaps, not affording perfect proof of the existence of a law on the development of consumption (in Massachusetts), which law has for its central idea that dampness of the soil in any township or locality is intimately connected with the prevalence of consumption in that township or locality."

But though it is, perhaps, hardly possible to furnish more convincing proof of the advantage to be gained by draining artificially the subsoil lying beneath and surrounding dwellings than by citing instances, where nature herself affords the proof without any help from man, it will probably be considered more pertinent if I point out the fact, that the strongest evidence yet afforded in support of this view has been given in cases where sewers which were intended primarily for the discharge of liquid refuse, have acted accidentally in the double capacity of drains and sewers, and have drawn out of the subsoil the water rising up within it, while discharging the sewage they were originally intended alone to remove. This is best shown by Dr. Buchanan's report "*Upon the Results of Works for Promoting Public Health*" (Ninth Report of Medical Officer of Privy Council, 1866), by which it appears that the general death-rate of Newport in South Wales was reduced 23 per cent., while the ailments known as "phthisis" were reduced 32 per cent. At Cardiff, the general death-rate was reduced 24 per cent., and the death-rate from phthisis 17 per cent. At Salisbury, the general death-rate was reduced 9 per cent., and that due to phthisis 49 per cent.

It must not be supposed, however, that I am advocating the construction of sewers to act generally in this way; I regard the practice as a species of engineering which we ought to avoid, inasmuch, as the same apertures which let the water from the subsoil into the sewer will let the sewage out of the sewer into the subsoil, whenever the pressure from within is greater than that from without. And we must also remember that wherever sewage itself escapes, sewer gases will escape too. This practice no Engineer can defend. Though good has come out of evil, we must never forget that the sewage and sewer air which escape may each rise up in the ground in the neighbourhood of sewers, and render it, to use the words of Mr. Simon, "excrement-sodden," and the air "excrement-reeking." This is evidently the case in several of our seaboard towns, where the sewage is retained in the sewers by the rising of the tide, and which are thus converted into cesspools.

When saying this I would not hide from myself, nor from you, the fact that soil where drained and aërated has an almost *im-*

measurable power of cleansing any liquid that may enter and pass through it, and thus defective work may be rendered harmless. In villages where shallow wells are retained for the supply of water in opposition to the advice and in face of the analyses of the chemist, an aërated crust of soil, seven or eight feet thick, will do much to remove by oxidation the evil of pollution arising from the infiltration of organic matter.

The drainage of the subsoil, wherever it is wet, should be effected by under-drains, which are altogether independent of the sewers, or which are only connected with them for the purpose of utilizing the subsoil water as a means of flushing the sewers.

XIII.—Wet Soils injurious to the General Health of Districts. We are not dependent upon towns for illustrations of the benefit to be derived from lowering the subsoil water. Wide agricultural districts have been so much benefited by drainage, that diseases which in former times constantly prevailed have now ceased to exist. From the Fens, ague, which had been the rule in every family during the spring of the year, has now been almost entirely banished by the works of Rennie and other Engineers; although since it first ceased to exist, the disease has recurred—not at the same period of the year (*spring*) as before, but, as I am informed by Mr. William Marshall, of Ely (the accuracy of whose observations as a naturalist is well known), in the *autumn* of the year—a special circumstance, which, he says, has been explained by the fact, that "the drainage had been carried beyond the point of prudence, so that in the summer months, and especially towards harvest, the Fen ditches became *nearly dry*, and the consequence was, that we once more got an exhaling surface, and a noxious effluvium arising from decaying vegetable matter." Mr. Marshall in further explanation adds that "this state of things is now quite altered, and the ague has again vanished, owing to the farmers making it a rule to let water in from the rivers during the summer months, so as to 'keep a water' always in the Fen ditches."

I thus shortly refer to these facts, because they clearly prove to the engineer how a locality naturally unhealthy may be made salubrious by *judicious drainage*, as certainly as the collection of filthy liquid in the midst of populations may be removed by *sewerage*.

XIV.—An Improved Temperature of the Atmosphere immediately incumbent on Surfaces gained by the Drainage of the Subsoil. But the advantage of lowering the subsoil water, and of admitting air into the soil does not end with the reduction of special

diseases. This work has the effect of improving the temperature of the air incumbent upon the ground, as well as of raising that of the soil beneath. If the rain falling on the ground is absorbed, and cannot escape from the subsoil because no outlets exist to carry it away, it is evaporated from the surface; and supposing 30 inches of rain to fall in a year on an acre of land, and its evaporation to be spread over the whole period, the daily weight of water evaporated would be rather more than $8\frac{1}{4}$ tons, or 18593 lbs.

An engineer will best realize the loss of heat, *i.e.*, the reduction of temperature, resulting from the change of such a quantity of water into vapour, when he remembers that it would require "the combustion of about 24 cwt. of coals, as ordinarily used under a steam boiler, to effect the object." (*Josiah Parkes*), "*cæteris paribus* the amount of water evaporated is proportional to the surface exposed to air. It is much greater from porous solid substances kept wetted—as, for example, moist soil wetted by rain—than from the surface of water itself." (*Herschel.*) Every grain of water evaporated carries off with it sufficient heat to raise 960 grains, one degree Fahr.

Mr. Buchan, of the Scottish Meteorological Society, has shown by his experiments, "that the temperature of drained soil has been raised in summer above that of undrained land to the extent of three degrees, often two degrees, and still more frequently a degree and a half; hence, it follows that the advantage derived from drainage is in many cases the same as if the land had been transported 100 or 150 miles southward."

Dr. William Rankine showed (*Journal of the Scottish Meteorological Society*, 1865) that the mean temperature of land was raised by under-drainage, at 10 inches from the surface, $\frac{8}{10}^{\text{ths}}$ of a degree, while the experiments I made at Hinxworth (*Journal of the Royal Agricultural Society of England*, vol. xx., 1860) showed that in spring the temperature of drained land at 18 inches from the surface was two degrees higher than that of undrained land at the same depth. The experiments of the late Josiah Parkes, near Bolton-le-Moors, showed an increase in the temperature of drained land over undrained bog of 10 degrees, at 31 inches below the surface (*On the Influence of Water on the Temperature of Soils, Journal of the Royal Agricultural Society of England*, vol. v.) Professor Schubler's experiments at Tubingen and Geneva proved that rain falling on aërated (*i.e.*, drained) land, while supplying moisture also supplied warmth, and raised the mean annual temperature of ground 6° at a depth of four feet, while in support of the deep drainage of ground Herschel states, on the authority of Quetelet

(*Mem. Acad., Brussels*, 1836), "that the fluctuations of temperature beneath the surface grow continually less as the depth increases," and the difference between diurnal and nocturnal extremes becomes imperceptible at four feet below the surface.

A telling demonstration of the improved condition of a district by under-drainage was given by the late Lord Palmerston, who, on the completion of the Broadlands drainage, tersely expressed to me his approval, by saying, "*You have saved me a great-coat.*"

XV.—THE MAINTENANCE OF PURE AIR BY THE UNDER-DRAINAGE OF THE SOIL SURROUNDING AND BENEATH DWELLINGS, AN OBJECT ONLY INFERIOR IN IMPORTANCE TO THE REMOVAL OF PUTRESCIBLE MATTERS. That this object is one of the most important that can engage the attention of the sanitary engineer cannot be denied, when it is shown on the authority of Dr. de Chaumont that long continued exposure to bad air tends to the production of scrofula and consumption—of which latter disease it is, as already stated, probably the most efficient cause—that it promotes enteric fevers, that it fosters ailments of the respiratory organs, such as catarrh, bronchitis, and pneumonia, that it is frequently the cause of inflammation of the eyes, and that it adds to the spread of small-pox, measles, scarlet fever and the like, while it renders the rapid cure of wounds and sores of all kinds a work of great difficulty.

I should not have laid so much stress upon under-drainage, in contra-distinction and in addition to sewerage, as the work of the engineer, were it not that I am convinced that the present generation—which has adopted as an axiom the saying of Franklin, that "public health is a nation's wealth"—will be reproved by the next for not making the drying of the soil a fundamental requirement in sanitary works. I feel assured, that as certainly as we of this generation are now engaged in removing from our rivers the polluting matters which the authorities of the last obliged our fathers to discharge into them, so will those who come after us lament with shame, and do their best to repair, the disregard paid by our present authorities to the drying of the sites of habitations as one of the first considerations for the preservation of human life.

DIVISION II.

WATER.

XVI.—The Constituents of Normal Water. Water in its normal state consists of only two elements, hydrogen* and oxygen in the proportion of two volumes of the former gas to one of the latter, or by weight 11·11 per cent. of hydrogen to 88·88 per cent. of oxygen.

In water the two gases of which this substance is composed are chemically combined, and, unlike the constituents of air, which remain unaltered, they lose their gaseous form and their distinctive properties, both physical and chemical, and become a new substance.

XVII.—Water: How Polluted. Water is, however, no sooner in existence than it loses its normal condition by the absorption of foreign matters with which it comes in contact, and which detract from its purity. This depreciation takes place in its first condition as the vapour of the atmosphere; then as that vapour changes into rain and falls to the ground; then as the collected rain passes over the surface of the earth on its way to the rivers, or, if absorbed, as it percolates through the soil to the subterranean water levels beneath; then as it passes through the earth to find outlet at the surface in the beds of rivers and streams, or at impervious outcrops in the shape of springs; and, lastly, as it is discharged to the sea after it has assumed the form of rivers and tributary streams.

In its condition as vapour and as rain, water is defiled by the gases of putrefying organic matters, which rise into the air from the surface of the earth, while as dew and hoar-frost it is affected by the same causes only in a greater degree. As vapour and rain too, water is also rendered impure by smoke from burning,

* Hydrogen is a colourless, tasteless, and inodorous gas, 14½ times lighter than atmospheric air. It is very inflammable, and burns in air with a pale flame, producing water by combining with atmospheric oxygen.

and by emanations from mineral substances used in manufacture; as collected rain passing over impervious surfaces towards the rivers and their tributaries, water gathers those organic and inorganic impurities which are more or less associated with cultivated and uncultivated lands, and with sparsely populated as well as closely populated districts; and when percolating and travelling through the earth, water mixes with any organic matter that may have already found its way into the ground from the surface, while its chemical qualities are profoundly influenced by the character of the geological formations through which it passes, and by its mixture with salts and dissolved substances existing in the earth.*

When the rain after accumulating in the bowels of the earth has found outlet in springs, and has taken the shape of rivers and streams, it is further polluted by the influx of the excrements of animals, and the liquid refuse of all kinds from human habitations in consequence of those rivers and streams acting as natural drains for the districts through which they flow. Moreover, water when utilized may be affected, and often is affected, by the materials of which tanks, cisterns, and delivering conduits are composed, and the way in which the last are jointed.†

XVIII.—Quantity required for Consumption and Use. The quantity of liquid which is drunk by human beings necessarily varies with the age and occupation of the consumer. The *average* quantity drunk by both sexes of all ages and of different occupations is really very small, when compared with the quantity we are accustomed to consider is required by the population of this country. It does not reach three pints per head a day, and this covers every description

* "The influence of geological formation upon the palatability and wholesomeness of *surface water* is often inconsiderable, owing to the deposit of peaty matters upon the surfaces of the rocks and soils—unpolluted surface waters from the most widely different geological formations differing but little in the proportions of organic matter which they contain; but where the water percolates or soaks through great thicknesses of rock, its quality, when it subsequently appears as *spring or deep well water*, depends greatly upon the chemical character of the material through which it has passed. When the formation contains much soluble saline matter the water becomes loaded with mineral impurities, as is frequently the case when it percolates through certain of the carboniferous rocks, the lias and the saliferous marls. When the rock is much fissured or permeated by caverns or passages, like the mountain limestone, for instance, the effluent water differs but little from surface drainage, and retains most of the organic impurities with which it was originally charged.

"But when it is uniformly porous like the chalk, oolite, greensand, or new red sandstone, the organic matter at first present in the water is gradually oxidized and transformed into innocuous mineral compounds."—*Rivers Pollution Commissioners.*

† To appreciate the effect of impurity of water upon the animal economy, the reader is referred to the report of Dr. Hofman and Professor Blyth, (1856), see Appendix C.

of liquid consumed. It savours of the ridiculous to speak of water-famine when the total quantity of liquid (of every description) drunk by each person does not, in fact, exceed in amount the quantity of water that would fall as rain in twelve months upon a good-sized umbrella if exposed for the purpose in either of the counties of Devon or Cornwall. From the *Report on the Army and Navy Diet Scales* I find, that the estimated quantity of liquid of all kinds drunk in the two services averages 187½ gallons per head per annum, or about two quarts per day. Though this quantity is drunk by adults of the male sex it is some criterion of the quantity drunk by men, women, and children, and it will not be wrong to assume that two-thirds, or 125 gallons per head, is as much as is actually consumed by a mixed population in a year. Dr. Parkes says that an *adult* requires daily from 70 to 100 ounces (3½ to 5 pints) for nutrition, but about 20 to 30 ounces of this quantity are sometimes in the solid food.*

The water we drink, however, is, as we all know, not the only water that affects human health. All water mixed with solid food, and used for cooking, and I would add, the water used for personal ablution, and for the washing of the clothes we wear, and the utensils used in cooking, have a material though not so direct an influence on our sanitary condition. The quantity used in these different ways, when added to that which is drunk in one shape or another by the various descriptions of persons and communities of which all populations consist, does not together reach eight gallons per head, and in rural districts will not amount to half that quantity.

Eight gallons may be safely taken as representing the extreme quantity of water required of which the quality must be of the purest.

The additional supply required for every household purpose,—if the rules of cleanliness are duly observed,—including the water used in closets, and in washing floors, &c., as well as that used in stables, in the washing of carriages, and for other outside purposes, increases the 8 gallons to 15 gallons per head. All beyond this quantity taken for private use is mere waste, which would cease to exist if, in addition to a fixed charge for that quantity, every consumer paid for what he had besides.

It will have been understood, that this quantity of 15 gallons per head is exclusive of the water used in trade, and of that devoted to public purposes, which, taking the mean quantity used in ordinary towns—I do not refer to towns in which special trades prevail—will

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* The living animal is made up for the most part of water. A "model" man of 154lbs. contains 116lbs. of water, and only 38lbs. of dry matter.—*Johnston.*

be found to amount to 10 gallons per head, thus raising the total consumption to 25 gallons per head. I have found on investigating the quantity of water used in different trades that as much as two millions of gallons per diem have been used in one business alone. It is difficult to strike an average, when such extremes as this are included, for such a quantity would, in truth, serve a town with a population of 80,000, consuming 25 gallons per head.

Disregarding such extraordinary uses, I believe that we may take 25 gallons per head per diem as an ample supply for the generality of towns, while 15 gallons will suffice for rural villages; the supply of more than these quantities of water only results in waste.

XIX.—For this Section see tabulated sheet XIX.

XX.—Yearly and Monthly Rainfall. The quantity of water placed at the disposal of man may be stated to depend, primarily upon the amount of rainfall, and secondarily, upon the quantity thrown off the surface after satisfying vegetation—which is available for storage above ground—and the quantity absorbed by porous surfaces after satisfying both vegetation and evaporation—by which nature's underground storage is maintained.

The rain falling in different countries and places varies very greatly in quantity, in season, and in the circumstances which would influence its collection, conservation and use.

At Cracow the annual fall is ...	Europe	$13\frac{1}{3}$	inches.
„ Brussels „ „ ...		$28\frac{1}{2}$	„
„ Rome „ „ ...		31	„
At Calcutta „ „ ...	Asia	$76\frac{1}{2}$	„
„ Bombay „ „ ...		$75\frac{1}{6}$	„
At Washington „ „ ...	America	$41\frac{1}{6}$	„
„ Charleston „ „ ...		54	„

For our present object, it will suffice if I limit my observations to the annual depth of rain falling upon the surface of England and Wales. It averages 32 inches.—*Symons.*

In England, the average monthly rainfalls on the two sides of the country, east and west, will be found to closely approximate those given in the following tabular statement, taken from *The Farm Homesteads of England*:—

	Public Use.	Remarks.
	—	
	—	
	—	Hardness before boiling 6°: after boiling 2·4°
	—	
	—	
	—	Supply from River Washburn, excepting 1 million galls. per diem which are obtained from gathering ground at Eccup. The works on the Washburn are not yet completed.
	£100 per annum.	£500,000 (in addition to £267,000) have been spent in new works, not yet quite complete, and £150,000 to £200,000 more will be required to carry out scheme as sanctioned.
	—	The construction of filter beds is now in contemplation.
	—	Free ammonia ·008, albuminoid ammonia ·034, and chlorine ·07 per 100,000 parts.
	Street water 3d. per load. Flushing 12s. 6d. p. hour run	
	No charge.	Analysis 1871, free ammonia ·0008, albuminoid ammonia ·007 per 100,000 parts.
	Street water gratis, remr. 1s. per 1,000 galls.	
	—	
	9d. per 1,000 gallons.	
	6,000,000 galls. free; 2½d. per 1,000 galls. for all beyond.	The Corporation represent ½ of the share interest of the Water Company, hence the small charge for public supply. About one-half the population is supplied from wells.
	—	Chlorine 1·98 grs. per gallon; free ammonia ·05 millige per litre; albuminoid ammonia ·32 millige per litre; nitrogen 1·78 millige per litre; permanent hardness = 11 grs. carbonate of lime per gallon.
	—	
	—	
	2½d. to 1s. 6d. p. 1,000 glns.	The water from the river Ely is gathered in a perforated brick culvert laid along the bank of the river in sand and gravel, overlying New Red Sandstone. Diameter of culvert 6′ × 4′
	£150 per annum.	
	—	The works belong to a private company.
	—	In addition to water charges, a special rate of 8d. is levied to pay off cost of works in 30 years.
	No charge.	Total fixed solids 16·800; organic matter 1·141 grs. per gallon.
	—	
	—	The quantity supplied for trade use is supplied from a mill-stream passing through the town.
	—	

WESTERN SIDE OF ENGLAND.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
Keswick ...	4·87	2·63	4·60	4·24	3·02	4·12	4·94	5·85	4·41	9·00	8·35	6·66	62·69
Lancaster	3·46	2·99	1·75	2·18	2·46	2·51	4·14	4·58	3·75	4·15	3·75	3·95	39·67
Manchester	2·31	2·56	2·09	2·01	2·90	2·50	3·69	3·66	3·28	3·92	3·36	3·83	36·11
Exeter	3·32	2·35	2·34	1·97	2·14	2·26	1·91	2·59	2·60	3·69	4·67	2·74	32·58
Truro	4·66	3·79	3·44	2·54	2·41	2·79	2·64	3·04	3·68	4·08	6·11	4·90	44·08

EASTERN SIDE OF ENGLAND.

York	1·72	1·02	1·19	1·50	1·41	2·35	2·65	2·93	2·08	2·09	1·75	1·31	22·00
Boston	1·59	1·45	1·52	1·50	2·17	2·41	2·77	2·83	2·24	2·72	2·26	1·44	24·90
Norwich ...	1·97	1·45	1·16	1·79	1·91	1·77	3·10	2·76	2·48	2·94	3·02	1·74	26·09
Chiswick ...	1·95	1·66	1·43	1·40	1·85	1·79	2·05	2·75	2·37	2·92	2·70	1·53	24·40
Cobham ...	2·24	2·38	1·72	1·21	3·19	1·44	2·27	2·93	3·57	2·88	4·41	1·96	30·20

In the higher grounds of the west, the annual depth ranges from 30 to 75 inches, while in the flatter lands of the east it varies from 17 to 35 inches. The total quantity of rain which falls on an average of years on the surface of England and Wales amounts to 27,019,632,000,000 gallons. This gives an average covering of 723,904 gallons to an acre of surface.* Of course these figures do not afford any very tangible data for practice, as each requirement must stand on its own merits, but they give evidence of the ample scope which is at the engineer's command for providing a supply of water for all purposes.

They show that each acre of surface,—even in the eastern districts of England, where the average rainfall does not exceed half that of the western districts—receives as rain nearly 80 times as much water as an average member of the population requires.

At Greenwich, where reliable guaging has been adopted since 1815, the annual average from that date has been 25·36 inches, the maximum reaching (1824) 36·3 inches, and the minimum falling to 16·8 inches. The maximum is generally estimated by engineers to be one-third in excess of the average rainfall, and the minimum one-third below it.

Mr. George Dines, the well-known builder of Pimlico, has prepared some very interesting diagrams and tables showing the rainfall in the metropolis for the last 60 years, and the mean quantity of rain

* An inch of rain falling on an acre of surface gives 22,622 gallons of water, and if 12 inches only be collected a supply will be gained from a single acre sufficient to satisfy 30 persons all the year round with 25 gallons of water each daily.

due to each month. The result places the different months in the following order, and I have added for comparison the monthly rainfall of the eastern and western sides of England :—

1813—72.	Rainfall in Metropolis.	Average Rainfall of the East and West Sides of England.		1813—72.	Rainfall in Metropolis.	Average Rainfall of the East and West Sides of England.	
		East.	West.			East.	West.
	Ins.	Ins.	Ins.		Ins.	Ins.	Ins.
October	2·74	2·71	4·97	December	1·93	1·60	4·42
September	2·35	2·55	3·54	January	1·91	1·89	3·72
July	2·32	2·57	3·46	April	1·66	1·48	2·59
November	2·28	2·83	5·25	March	1·52	1·40	2·84
August...	2·26	2·84	3·95	February	1·50	1·59	2·86
May	2·07	2·11	2·59				
June	2·01	1·95	2·84		24·55	25·52	43·03

From these figures it will be seen that the wettest months of the year in London are September, October, July, and November, and that there is only some slight difference in this particular between London and the rest of the country. With the exception of July these months occur when summer is on the close, when vegetation no longer requires the same support of moisture as previously, and when evaporation necessarily becomes less active with increased moisture and reduced temperature. It is when such conditions prevail that the larger proportion of the rainfall is rendered available for use by storage above ground if collected from saturated and impervious surfaces, or serves to replenish the subterranean supply which nature stores under our feet in the water-bearing strata.*

It will be found that in accordance with the amount of the winter's rainfall, especially that of the months of September, October, and November, so will the following summer's subterranean supply be decreased or increased in some measure by the amount of the rainfall of the antecedent winter. If, for instance, two dry winters succeed each other the drought of the following summer will be proportionately increased. The following tabular statement shows the relative quantities of rain that have fallen in winter and summer during the last six years, and this may be studied very usefully in connection with the tables given in the next section :—

* The reader is referred to a very interesting table extracted from the evidence given by Mr. Hawksley, C.E., before the Water Supply Commission, showing the three consecutive months in each year for 20 years, which had the maximum and minimum fall of rain at Sheffield (see Appendix E.)

	1867-8.		1868-9.		1869-70		1870-71		1871-2.		1872-3	
	Winter—Oct. to March inclusive.	Summer—April to Sept. inclusive.	Winter—Oct. to March inclusive	Summer—April to Sept. inclusive.	Winter—Oct. to March inclusive.	Summer—April to Sept. inclusive.	Winter—Oct. to March inclusive.	Summer—April to Sept. inclusive.	Winter—Oct. to March inclusive.	Summer—April to Sept. inclusive.	Winter—Oct. to March inclusive.	Summer—April to Sept. inclusive.
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
East	10·80	8·33	16·17	12·76	12·81	8·01	13·92	14·41	10·45	16·61	15·79	10·68
South	13·39	12·92	17·69	12·47	13·47	5·51	15·76	19·30	20·94	16·23	27·48	10·46
West	18·50	13·61	26·58	16·47	17·09	10·47	17·42	19·40	19·31	24·32	22·04	16·95
North	10·10	9·85	16·09	10·77	12·72	7·46	16·42	18·64	14·60	21·43	19·57	11·92
Mean of wintr	13·20	—	19·13	—	14·02	—	15·88	—	16·32	—	21·22	—
Mean of sumr	—	11·18	—	13·12	—	7·86	—	17·94	—	19·65	—	12·50
Year	24·38		32·25		21·88		33·82		35·97		33·72	

Average of the six years, 30·34 inches.

XXI.—Infiltration of Rain by Absorbent Soils in Summer and Winter. The proportion of the rainfall absorbed by and penetrating a porous surface to maintain the river systems varies considerably. On an average of years we find that from one-fourth to one-third of the rainfall according to the nature of the soil and state of husbandry thus descends to the subterranean levels. The quantity which infiltrated the chalk district in the neighbourhood of King's Langley to replenish the springs and rivers of that neighbourhood, was ascertained and recorded by the late Mr. Dickenson, the well-known paper maker of King's Langley and Hemel Hempstead, up to the time of his death, by means of a gauge devised by Dalton of Manchester. The records have been continued from that date by his successor Mr. Evans, the President of the Geological Society. The gauge is fixed in the ground three feet below the surface, and not only is the quantity of rain that finds its way down to it indicated, but, by deducting that quantity from that which falls on the surface, and which is carefully gauged and recorded, the observer may ascertain the amount of water evaporated.

The following table gives the rainfall and percolation (through Dalton's Gauge, filled with surface soil) at Nash Mills, Hertfordshire, from the year 1835 to 1860 :—

Year.	Winter.		Summer.		Year.	Winter.		Summer.	
	Rainfall.	Percolation.	Rainfall.	Percolation.		Rainfall.	Percolation.	Rainfall.	Percolation.
	Ins.	Ins.	Ins.	Ins.		Ins.	Ins.	Ins.	Ins.
1835-6	16·39	14·27	12·20	2·10	1851-2	10.75	3·66	19·97	1·50
1836-7	16·71	13·81	9·80	·10	1852-3	20·27	10·74	16·79	·24
1837-8	9·81	5·45	10·81	·12	1853-4	9·66	4·22	9·47	—
1838-9	12·58	8·59	17·41	2·60	1854-5	9·32	2·45	13·66	·19
1839-40	14·71	13·59	9·68	—	1855-6	14·48	6·82	14·86	2·79
1840-1	10·32	3·10	16·95	—	1856-7	11·96	3·73	14·11	1·11
1841 2	16·56	17·98	12·15	1·30	1857-8	11·81	5·64	12·27	·80
1842-3	13·46	9·34	14·04	·99	1858-9	9·64	·09	18·31	—
1843-4	15·41	8·86	8·07	—	1859-60	16·49	9·27	20·40	3·16
1844-5	13·11	7·10	11·57	—					
1845-6	13·93	9·01	11·50	·28					
1846-7	12·93	5·84	11·31	—	Average 25 years	13·317	7·506	13·293	·721
1847-8	15·84	8·94	13·00	·70					
1848-9	13·49	6·22	13·91	—					
1849-50	8·56	1·44	11·82	—	Difference—evaporated or lost	5·811		13·571.	
1850-1	14·71	8·49	9·25	·04					

Total average rainfall	26·609	Inches.
Percolation	8·227	,,
Difference—evaporated or lost	18·382	,,

On comparing this table with one which was contributed to the *Proceedings of the Institution of Civil Engineers* by Mr. Charles Greaves, C.E., the Engineer will find the records of Messrs. Dickenson and Evans, confirmed if allowance is made for difference of soil :—

TABLE OF RAINFALL AND PERCOLATION (THROUGH DALTON'S GAUGE, FILLED WITH NATURAL SOIL) AT LEE BRIDGE DURING THE YEARS 1852 TO 1873.

Year.	Quarter ending.	Rain.		Percolation.		
		Quarter.	Year.	Quarter.	Year.	
		Ins.	Ins.	Ins.	Ins.	
1851	December	4·0	...	0·75	...	
1852	March	6·0	...	2·50	...	
	June	7·5	...	1·00	...	
	September	9·0	26·5	1·00	5·25	
	December	11·0	33·5	6·87	11·37	
1853	March	5·5	33·0	2·00	10·87	
	June	8·0	33·5	1·00	10·87	
	September	9·0	33·5	1·00	10·87	
	December	6·0	28·5	1·50	5·50	
1854	March	3·5	26·5	0·50	4·00	
	June	5·0	23·5	...	3·00	
	September	4·0	18·5	...	2·00	
	December	5·0	17·5	0.75	1·25	
1855	March	4·021	18·321	0·674	1·424	Very dry.
	June	1·917	15·238	0·030	1·454	
	September	8·776	19·814	...	1·454	

TABLE—*Continued.*

Year.	Quarter ending.	Rain.		Percolation.		
		Quarter.	Year.	Quarter.	Year.	
		Ins.	Ins.	Ins.	Ins.	
1855	December	10·000	24·714	2·000	...	
1856	March	4·812	25·505	3·725	5·755	
	June	7·021	30·609	0·136	5·861	
	September	6·937	28·770	...	5·861	
	December	5·042	23·812	0·999	4·860	
1857	March	5·105	24·105	2·590	3·725	
	June	5·667	22·751	...	3·589	
	September	9·710	25·524	1·925	5·514	
	December	8·145	28·627	3·825	8·340	
1858	March	4·605	28·127	1·950	7·700	
	June	7·410	29·879	1·225	8·925	
	September	6·332	26·501	0·175	7·175	
	December	5·543	23·899	0·150	3·500	
1859	March	3·311	22·605	0·750	2·300	
	June	7·687	22·873	0·500	1·575	
	September	7·895	24·436	0·100	1·500	Very dry.
	December	8·874	27·767	6·036	7·387	
1860	March	5·227	29·683	3·175	9·812	
	June	10·520	32·516	2·387	11·699	
	September	9·312	33·933	1·837	13·436	
	December	7·499	32·558	3·362	10·761	
1861	March	6·266	33·597	2·762	10·348	
	June	4·141	27·218	0·187	8·148	
	September	5·374	23·280	...	6·311	
	December	7·852	23·633	2·762	5·711	
1862	March	6·645	24·012	3·437	6·386	
	June	7·813	27·684	1·649	7·848	
	September	5·332	27·642	...	7·848	
	December	6·791	26·581	3·462	8·549	
1863	March	4·062	23·998	2·387	7·408	
	June	5·270	21·455	...	5·849	
	September	5·206	21·329	...	5·849	
	December	5·228	19·766	1·374	3·761	
1864	March	4·728	20·432	2·862	4·236	
	June	3·770	18·932	0·062	4·298	
	September	3·936	17·662	...	4·298	Very dry.
	December	3·457	15·891	0·899	3·824	
1865	March	7·145	18·308	5·425	6·386	
	June	5·083	19·620	0·025	6·349	
	September	7·896	23·580	0·837	7·186	
	December	9·124	29·248	4·862	11·150	
1866	March	9·291	31·394	7·575	13·299	
	June	7·895	34·206	1·425	14·699	
	September	7·855	34·165	...	13·862	
	December	6·655	31·697	3·587	12·587	
1867	March	8·333	30·738	4·287	9·299	
	June	5·749	28·593	0·087	7·962	
	September	8·729	29·467	...	7·962	
	December	4·623	27·436	0·787	5·162	
1868	March	6·437	25·538	3·812	4·686	
	June	3·662	23·451	0·037	4·636	
	September	4·166	18·888	...	4·636	Very dry.
	December	9·041	23·308	3·262	7·112	
1869	March	7·000	23·868	5·325	8·624	
	June	5·395	25·601	0·162	8·749	
	September	4·354	25·789	...	8·749	
	December	7·812	24·562	2·562	8·050	
1870	March	4·854	22·415	3·262	5·986	
	June	1·604	18·624	0·050	5·874	
	September	5·354	19·624	...	5·874	
	December	8·583	20·395	3·912	7·225	
1871	March	5·458	20·999	3·800	7·762	
	June	6·062	25·457	0·375	8·087	

TABLE—*Continued.*

Year.	Quarter ending.	Rain.		Percolation.		
		Quarter	Year	Quarter	Year	
		Ins.	Ins.	Ins.	Ins.	
1871	September	8·916	29·019	0·075	8·162	
	December	3·645	24·083	1·937	6·187	
1872	March	8·208	26·831	4·880	7·247	
	June	7·624	28·393	1·075	7·947	
	September	7·020	26·497	...	7·872	
	December	14·312	37·166	6·100	12·035	
1873	March	6·020	34·976	2·937	10·009	
	June	5·062	32·414	...	9·037	
	September	6·875	32·269	...	9·037	
	December	5·812	23·770	1·112	4·050	

	Inches.
Total average rainfall...	25·837
Do. percolation	6·866
Difference evaporated...	18·971

Comparing the results of the two series of observations, it will be seen that, while the average amounts of rainfall differed less than one inch, the quantity of rain that found its way down to the gauge at Hemel Hempstead exceeded that at Lea Bridge by about $1\frac{1}{3}$ inches, the former being 8·227 inches, and the latter 6·866 inches. It should be observed that in neither case has any overflow been recorded, so that the rainfall which, on occasions of storms, would to some extent run off the surface, has been included in the percolated quantity.

XXII.—QUANTITY OF RAINFALL EVAPORATED OR LOST FROM ABSORBENT AND NON-ABSORBENT SURFACES. The difference between the amounts of rainfall and percolation given in the foregoing tables represents, as I have stated, the amount of rain lost each year by evaporation, including the small proportion which, with undisturbed soils, would overflow even a porous surface at times of extreme downfalls of rain, when the rapidity of descent will prevent absorption. For practical purposes we may assume that from 17 to 22 inches are lost by evaporation from the porous surfaces of this country.

The proportion of rainfall evaporated and "lost" from non-porous surfaces is quite another matter, and I am not in possession of any data by which to give the amount. Engineers are

accustomed to adopt arbitrary rules of their own—modified by the circumstances, physical and meteorological, of each case—when they desire to arrive at the nett quantity of water which can be collected from various gathering grounds, and there is ample reason for the practice. Mr. Bateman, C.E., states the loss by evaporation to vary from 9 to 16 inches, "the average being 12 inches." The late Mr. Hemans, C.E., considered that "the mean will amount to 12 or 14 inches." Mr. Duncan, C.E. (Liverpool), found by actual measurement that the loss varied very little, though the difference of rainfall was considerable. He considered 11 or 12 inches was the "constant" loss (at Liverpool). Mr. Hawksley, C.E., has stated that "it amounts rarely to so little as 11 and 12 inches, and very commonly upon hilly ground to 13, 14, and 15 inches." "Evaporation," says Mr. Hawksley, "is more nearly 15 inches than any other quantity."

XXIII.—Quantity of Rainfall thrown off Pervious and Impervious Surfaces and available for Storage. The quantity of water in excess of that which is absorbed and evaporated from pervious (or porous) surfaces, and impervious (or non-porous) surfaces, and which runs off the surface into our rivers, and by our rivers to the sea, and is therefore available for storage on the surface, necessarily varies as much as any other condition affecting the water question.

Taking a general view of the matter, it may be stated that on the northern and western side of the country, including Wales, the amount of surface water at the disposal of man for storage, though it varies in different parts in a remarkable degree, cannot be less on an average than 20 inches, if we include in the estimate the highest and mountainous surface found in the wettest districts.

In the Midland, Southern, and Eastern Districts the mean depth of water run off in the shape of floods and freshets, and in like manner available for storage, has been represented to be six inches, though, if the outflow of the Thames may be taken as a criterion, a less quantity would perhaps be more correct.

Some interesting information bearing on this point was given by Mr. J. Thornhill Harrison, before the Water Supply Commission in 1867, from which it appeared that the average annual *dry* weather outflow of the Thames was 6·86 inches. The period of observation extended over 11 years, from the 1st April, 1855, to the 31st March, 1866, during which time the mean annual fall of rain in the Thames Basin was 27·74 inches, while the mean annual discharge of

water by the river, measured at Kingston, was 9·25 inches, or 2·39 inches more than the average dry weather outflow just noted.

The minimum annual discharge of the Thames during the 11 years was that of the year ending the 31st March, 1859, when it was reduced to 5·49 inches, or 1·37 inches below the average dry weather outflow. The rainfall of the year 1857 had been 22·76 inches, and that of 1858 24·60 inches, with a remarkably dry winter intervening. The Engineer will apply these figures in connection with Sections XXI., XXII., XXIII., and LXIV.

XXIV.—Waters Classified and Analysed according to Source. To exhibit the quality of water to be obtained from different sources there is no better classification than that by which I have already traced the passage of water from the condensation of atmospheric vapour into rain to its outflow from the earth.

In the sixth report of the Rivers Pollution Commissioners, which is a comprehensive exposition of the *chemical* view of the water question, the different waters obtainable in this country are treated in this order, and their classification is given in the following terms :—(1) Rain water; (2) Upland surface waters from uncultivated, or but slightly cultivated, surfaces not manured; (3) Surface waters from cultivated lands; (4) Shallow well waters; (5) Deep well waters; and (6) Spring waters.

The following analyses, from the same report, show the composition of water derived from these different sources :—

AVERAGE COMPOSITION OF WATERS DERIVED FROM VARIOUS SOURCES.

(*Results of Analyses expressed in parts per* 100,000.)

Description of Water and Geological Formation.	No. of samples from which the average is taken.	Dissolved Matter.								
		Total solid impurity.	Organic carbon.	Organic nitrogen.	Ammonia.	Nitrogen as nitrates and nitrites.	Total combined nitrogen.	Previous sewage, or animal contamination.	Chlorine.	Permanent hardness.
Rain Water	73	3·95	·099	·022	·050	·007	·071	220	·63	1·7
Upland Surface Waters. Non-calcareous strata. Igneous rocks	18	5·15	·278	·033	·001	·002	·035	0	1·13	2·0
Metamorphic, Cambrian, Silurian, and Devonian rocks	81	5·12	·293	·024	·002	·006	·031	3	·92	2·5

TABLE—*Continued.*

Description of Water and Geological Formation.	No. of samples from which the average is taken.	Dissolved Matter. Total solid impurity.	Organic carbon.	Organic nitrogen.	Ammonia.	Nitrogen as nitrates and nitrites.	Total combined nitrogen.	Previous sewage, or animal contamination.	Chlorine.	Permanent hardness.
Non-calcareous strata.										
Yoredale and Millstone grits, & the coal measures	47	8·75	·373	·037	·003	·010	·050	6	1·05	4·3
Lower London tertiaries & Bagshot beds	3	8·40	·379	·048	·004	·007	·058	0	2·06	3·5
Calcareous strata.										
Silurian and Devonian rocks	3	13·71	·302	·026	·000	·021	·047	77	1·20	7·4
Mountain limestone	7	17·07	·370	·047	·001	·011	·059	26	1·24	7·0
Coal measures	26	22·79	·346	·037	·003	·016	·056	33	1·52	8·3
Lias, new red sandstone, conglomerate sandstone, and magnesian limestone	9	18·80	·286	·042	·002	·010	·054	4	1·49	6·5
Oolites	1	17·46	·326	·025	·004	·042	·070	130	1·55	5·8
Surface Waters from Cultivated land.										
Non-calcareous districts	31	9·52	·276	·034	·007	·089	·128	635	1·49	4·3
Calcareous districts	144	30·08	·268	·053	·005	·257	·314	2306	2·24	8·2
Shallow Well Waters.										
Silurian rocks and gneiss	...	15·16	·059	·010	·000	·424	·434	3920	2·00	5·7
Devonian rocks	...	54·46	·096	·025	·001	·701	·727	6700	10·10	15·4
Yoredale & millstone grits		17·12	·055	·010	·000	·428	·438	3960	1·35	7·9
Coal measures	...	46·00	·271	·072	·003	1·043	1·117	10130	3·10	28·5
Mountain limestone and magnesian limestone	...	72·48	·126	·054	·002	1·812	1·868	17820	4·60	38·6
New red sandstone	...	94·32	·163	·031	·000	2·620	2·651	25880	5·10	37·2
Lias	...	94·04	·326	·102	·001	2·980	3·083	29490	8·65	13·2
Oolites	...	93·80	1·386	·326	·022	1·714	2·058	17000	9·20	27·1
Upper and Lower Greensand and Wealden beds	...	21·36	·143	·027	·003	1·076	1·105	10460	4·70	7·4
Chalk	...	56·32	·079	·051	·001	2·300	2·352	22690	4·47	18·3
Gravel resting on London clay	...	68·46	·263	·112	·052	1·214	1·369	12250	4·37	18·9
Bagshot beds	...	52·52	·317	·062	·001	1·399	1·462	13680	7·80	25·7
Fluvio-marine series	...	14·72	·142	·026	·000	·000	·026	0	2·90	5·9
Alluvium and gravel	...	61·72	·149	·040	·000	2·726	2·766	26940	6·55	20·0
Deep Well Waters.										
Devonian rocks and millstone grit	7	32·68	·068	·012	·005	·294	·310	2671	2·70	8·6
Coal measures	9	83·10	·119	·034	·044	·207	·278	2243	18·05	20·6
Magnesian limestone	3	61·14	·076	·030	·000	1·426	1·456	13937	4·31	26·9
New red sandstone	28	30·63	·036	·014	·003	·717	·734	6895	2·94	10·5
Lias	2	70·98	·146	·027	·001	·389	·417	3730	4·42	8·2
Oolites	5	33·60	·037	·010	·022	·625	·654	6118	2·69	6·3

TABLE—*Continued.*

Description of Water and Geological Formation.	No. of samples from which the average is taken.	Dissolved Matter.								
		Total solid impurity.	Organic carbon.	Organic nitrogen.	Ammonia.	Nitrogen as nitrates and nitrites.	Total combined nitrogen.	Previous sewage, or animal contamination.	Chlorine.	Permanent hardness.
Hastings sand, upper and lower green sand, and Weald clay	20	45·20	·068	·014	·016	·190	·223	1864	5·38	10·5
Chalk	66	36·88	·050	·017	·001	·610	·628	5801	2·76	6·5
Chalk beneath London clay	13	78·09	·093	·028	·048	·068	·135	797	15·02	8·7
Thanet sand and drift	4	53·84	·113	·020	·072	·116	·202	1517	6·32	7·6
Devonian rocks Coal measures New red sandstn. Lias Oolite Chalk Bagshot sand	Polluted 25	71·69	·233	·068	·019	1·383	1·467	13686	14·81	13·6
Spring Waters.										
Granite and Gneiss	8	5·94	·042	·008	·001	·106	·115	846	1·69	2·6
Silurian rocks	15	12·33	·051	·014	·001	·178	·192	1587	1·84	5·3
Devonian rocks and old red sandstone	22	25·06	·054	·012	·001	·764	·777	7339	3·85	7·2
Mountain limestone	15	32·06	·087	·010	·001	·224	·235	2008	4·63	8·9
Yoredale and millstone grits and coal measures	22	21·91	·050	·014	·001	·393	·408	3707	1·85	7·9
Magnesian limestone	1	66·52	·058	·038	·002	1·686	1·726	16560	3·40	34·8
New red sandstone	15	28·69	·065	·017	·001	·330	·349	3047	2·19	10·7
Lias	7	36·41	·073	·019	·001	·467	·487	4406	2·48	8·8
Oolites	35	30·33	·043	·011	·001	·402	·414	3730	1·55	6·2
Upper and lower green sand and Hastings sand	19	30·05	·053	·012	·000	·326	·338	2911	2·98	6·6
Chalk	30	29·84	·044	·010	·001	·382	·392	3511	2·45	5·5
Fluvio-marine, red crag, drift, and gravel	10	61·32	·086	·019	·001	·351	·374	3264	2·76	19·6
Polluted Spring Waters.										
New red sandstone	...	127·28	·186	·030	·001	1·712	4·743	46810	7·10	34·7
Oolite	...	40·62	·253	·041	·000	1·205	1·246	11730	2·60	11·0
Lower green sand	...	36·90	·146	·030	·001	·955	·986	9240	5·95	9·7
Gravel over London clay	...	154·70	·176	·057	·001	7·395	7·453	73840	27·50	34·1

XXV.—AVERAGE COMPOSITION OF UNPOLLUTED WATERS. In the "conclusions" arrived at by the Rivers Pollution Commissioners, and set forth in the report referred to, the average composition of "unpolluted waters" is given in the following form.

RESULTS OF ANALYSIS EXPRESSSED IN PARTS PER 100,000.

Description.	Dissolved Matters.											No. of samples taken.
	Total solid impurities.	Organic carbon.	Organic nitrogen.	Ammonia.	Nitrogen as nitrites & nitrates.	Total combined nitrogen.	Previous sewage, or animal contamination.	Chlorine.	Hardness.			
									Temporary.	Permanent.	Total.	
CLASS I. Rain water	2·95	·070	·015	·029	·003	·042	42	·22	·4	·5	·3	39
CLASS II. Upland surface water	9·67	·322	·032	·002	·009	·042	10	1·13	1·5	4·3	5·4	195
CLASS III. Deep well water.....	43·78	·061	·018	·012	·495	·522	4,743	5·11	15·8	9·2	25·0	157
CLASS IV. Spring water	28·20	·056	·013	·001	·383	·396	3,559	2·49	11·0	7·5	18·5	198
Average	—	·127	·019	·011	·222	·250	—	2·24	—	—	—	—

Without professing to appreciate thoroughly the expression "previous sewage or animal contamination," which is the heading to one of the columns, I give these figures because they may serve as "attainable standards" of pure water (from whatever source it may be derived), by leaving out, if desired, the speculative column just referred to.

XXVI.—CLASSIFIED RESULTS OF THE CHEMICAL ANALYSES OF WATERS. The chemical examination so carefully given to the subject led the Commissioners to adopt the following division of waters in the order of quality :—

"Wholesome" waters were declared to consist of

1. Spring water.
2. Deep well water.
3. Upland surface water.

"Suspicious" waters to be

4. Stored rain water.
5. Surface water from cultivated land; and the

"Dangerous" waters to be

6. River water to which sewage gains access.
7. Shallow well water.

Numbers 1 and 2 were stated to be "very palatable;" 3 and 4 "moderately palatable;" and 5, 6, and 7 "palatable." Preference is given to spring and deep well waters for purely domestic purposes over upland surface waters.

The conclusions come to by the Rivers Pollution Commissioners may be summed up in the following terms under their respective heads.

XXVII.—Wholesome Waters. Of all the waters obtainable in this country those that receive the preference of the Commissioners are spring and deep well waters. Such waters, they say, are of inestimable value to communities, and their conservation and utilization are worthy of the greatest efforts of those who have the public health under their charge. They say also, that water collected from the surface of uncultivated lands, when filtered through sand, constitutes upland surface water of good quality for domestic use, and of still better quality for manufacturing purposes. It is nearly always wholesome, but sometimes suffers in palatability from containing an excessive quantity of peaty matter in solution.

XXVIII.—Suspicious Waters. Of these the Commissioners say that when rain from specially cleansed surfaces is collected at a distance from towns, and kept in clean receptacles, it "contains the smallest proportion of total solid impurity, but the organic contamination even of such specially collected water somewhat exceeds that of water from springs and deep wells." Rain water collected from the roofs of houses, and stored in underground tanks, they state to be much more impure, while the water collected from the surface of cultivated lands, and from the under-drains of cultivated lands, is always more or less polluted with the organic matter of manure, even after subsidence in lakes or reservoirs. Such polluted surface or drainage water is, they declare, not of good quality for domestic purposes, but it may be used with less risk to health than polluted shallow well water, if human excrementitious matters do not form part of the manure applied to the land.

XXIX.—Dangerous Waters. In this class the Commissioners prominently place rivers and streams to which sewage gains access. They say: (1) that when the sewage of towns or other polluting organic matter is discharged into running water it is not possible to render that water fit for drinking; (2) that the admixture of a small quantity of the specific poisons capable of producing

cholera and typhoid fever with a large volume of drinking water is sufficient for the propagation of those diseases; (3) that "there is no river in the united kingdom long enough to secure the oxidation and destruction of any sewage which may be discharged into it even at its source;" (4) that artificial filtration constitutes no effective safeguard against the propagation of those epidemics by polluted water; and (5) with respect to "shallow well water," they state that whenever the wells are situated—as is usually the case—near privies, drains, and cesspools, it is more dangerous than river water.

The Commissioners therefore recommend the abandonment of rivers generally as a source of water supply wherever the liquid refuse of human habitation is admitted into them, and they unhesitatingly state that both the River Thames and the River Lee should be abandoned as a source of water supply for domestic use. In speaking of the Thames they say that "there is no hope of this disgusting state of the river being so far remedied as to prevent the admixture of animal and other offensive matters with the filtered Thames water as delivered in the metropolis." They therefore recommend that "the Thames should, as early as possible, be abandoned as a source of water for domestic use." In speaking of the Lee they say "the water of the Lee is slowly, though irregularly, deteriorating from year to year, and there is no hope of purifying it to such an extent as to render it at all times safe for domestic use." Consequently they "recommend that the Lee should be also abandoned as a source of potable water."

And as to the waters of shallow wells the Commissioners, having examined many samples from wells in different geological formations, declare them to be, with very few exceptions, "entirely unfit for human consumption." In speaking, however, of those in the new red sandstone they say that owing to the highly oxidizing power of the soil of this formation, the proportion of organic matter is generally more moderate than that met with in unpolluted surface waters.

XXX.—The Engineer's View of the General Question of Water Supply as thus presented by the Chemist. Such are the conclusions arrived at by the Rivers Pollution Commission on the most recent chemical investigation of the question. Dr. Edward Frankland, one of the most eminent chemists of the present age, was the leading member of that Commission, and the report in which his

conclusions are expressed will doubtless become, in the hands of students, a text-book on the chemistry of our national water supply. The Engineer, however, must condescend to a practical view of the question, and, without disregarding the valuable labours of the Commission, give full consideration to those local features and capabilities which govern cost, and which will therefore influence the selection of the source of supply in a greater or less degree.

XXXI.—Of so-called "Wholesome Waters"—Springs. Wherever springs bursting naturally from the outcrops of impervious strata in high grounds, or rising by pressure in valleys—which the Commissioners consider equal or superior in quality to the waters of deep wells—are available, the Engineer invariably turns them to account. Unluckily, however, springs of a superior potable quality, and of available quantity, exist only in exceptional places. They are extremely variable in character, and cannot therefore be considerered as a source of supply which can be generally or even frequently adopted.

XXXII.—Of so-called "Wholesome Waters"—Deep Wells. No Engineer will deny, as a general proposition, that water which has passed through natural soil, unaffected by any mineral impurity, to deep subterranean levels in the water-bearing strata, is, where available for use, the most acceptable of all waters for drinking purposes. Any organic matter which it may have contained will have been perfectly oxidized and transformed into innocuous mineral compounds when passing through the aërated soil, but inasmuch as the obtaining of water from deep wells is attended with many disadvantages, besides that of the great cost incurred in sinking and pumping, the Engineer cannot look forward to any very extended use of this source of supply for small villages, or for isolated dwellings.

I shall hereafter address myself to the subject of deep wells,—at the present time I will only point out to the Engineer that at Liverpool, where the water used in the town is partly obtained from wells sunk in the new red sandstone, the supply from that source is gradually lessening, and that to obtain the same quantity from the Bootle Well as heretofore, the authority has had "to go down somewhere over 50 feet." (See Mr. Duncan's evidence before the Water Supply Commission, 1867, and also Extract from Report of Mr. Deacon (1875), Appendix F).

That the effect of sinking deep wells in the new red sandstone is to lower very sensibly the water level, is supported by the fact

that when the Corporation of Liverpool sunk the Dudley Lane Well, such was the influence it had upon other wells in the vicinity that several became dry, and the owners converted them into cesspits for their liquid sewage, which in *its* turn found its way into the Dudley Lane Well.

We are told also by the Rev. James Clutterbuck, whose researches have been rewarded by a general acknowledgment of their great truth and value, that in the chalk under London, into which many wells have been sunk, the present water level compared with what it was fifty years ago, has been depressed 50 feet (see the evidence of Rev. J. Clutterbuck before the Water Supply Commissioners) showing distinctly—in the face of much that may be said in favour of deep wells as a means of supplying the Metropolis with water—that even in the case of so wide an area as the London Basin, the supply, if theoretically inexhaustible, can only be utilized by a disregard of existing interests and a disorganisation of the Thames River System. (See section showing the declension of the water level under London; Drawing II., Appendix). Nothing could make this more apparent than the fact that the great London brewers—even those having wells on different sides of the river—have been obliged to accommodate one another by pumping on alternate days. Some experience of the effect of pumping a large quantity of water out of the chalk of the London basin will soon be afforded by the Colne Valley scheme, just brought before the public.

At Southampton, Ipswich, Harwich, and other places, attempts have at different times been made and abandoned, because in some places there was an entire absence of water, and at others an insufficient supply, while in certain cases wells upon which large sums of money had been expended, have been declared useless from the water being salt or brackish, owing to the influx of tidal or sea water or to the presence of salt rocks in the formation. Moreover, the constant expense of raising water from deep subterranean sources, though a matter of indifference to wealthy cities and large towns, and even to the owners of large breweries and trade factories, is often so formidable as to put such a supply out of the reach of small village communities and private individuals scattered over the face of rural districts. (See Section LXIV.)

XXXIII.—Of so-called "Wholesome Waters"—Water collected from Uncultivated Surfaces. In mountainous and hilly districts, where sufficient areas of impervious gathering grounds

can be found, the best means of supply—because it is of a character over which the Engineer has most command—is that which the Rivers Pollution Commissioners have placed third and last on the list of "wholesome waters." I refer to the storage of rain water thrown off uncultivated surfaces and collected before it becomes contaminated by foreign matters.

In the northern and north-western districts of England the rainfall of the higher grounds is at present collected and stored for the use of many of our manufacturing towns, and experience has proved the superiority of the supply. The Sanitary Engineer will find many examples in this country which he would do well to study. The water works for the supply of Glasgow and Greenock, in Scotland, and those of Manchester, Sheffield, Barnsley, and many other places in England, are admirable specimens of the kind of source to which this section refers. Profiting by this experience, it has been proposed to convey waters that may yet be collected and stored in these districts to the metropolis and other populous places; but as the droughts of recent years have proved that scarcity may be felt even in the midst of abundant *average* rainfalls, this proposal has not gained favor, particularly since it has been advanced, with much force, that until the resources of each river basin have been exhausted, it would be opposed to national economy to appropriate the supply naturally belonging to other districts. It is held that the adoption of this proposal would prevent the future growth of those industrial communities which have located themselves in particular parts of the country in consequence of this very superabundance of water.

The conflict of opinion entertained on this question must have an important influence on the work of the Engineer, and the words of the Royal Commission on Water Supply, that "no town or district should be allowed to appropriate a source of supply which naturally and geographically belongs to a town or district nearer to such source," will meet with general approval.

XXXIV.—I think that I have said quite enough on the class of waters declared by the Rivers Pollution Commissioners to be "wholesome," and therefore preferable to all others, to show that the Engineer must in many instances have regard to other considerations besides those of superiority of quality. The question then arises from what sources is good potable water to be obtained in districts—notably those on the eastern side of England—in which towns, villages, and isolated dwellings now derive their supply for the most part from rivers and

shallow wells? This question has become a very urgent one with Engineers now that the Rivers Pollution Commissioners, without pointing out any other tangible means of supply, have so decisively condemned both sources and expressed very grave doubts as to the value of rain water, of water from roofs, and of the water to be gained from under-drainage.

XXXV.—Of so-called "Suspicious Waters,"—Waters to be collected from Roofs and other surfaces rendered artificially impermeable. If for the reasons already stated we cannot obtain deep well water, or spring water, or water from upland (uncultivated) surfaces for those towns and villages and dwellings which are scattered over the rural portion of the country, we are necessarily obliged to have recourse to those waters which are pronounced by the Rivers Pollution Commissioners to be "suspicious," *i.e.*, water collected from roofs and impermeable (artificially made) surfaces, water to be obtained from cultivated lands, and the water from under-drainage. These waters, they declare—as I have already said—to be always more or less polluted with organic matter; but in the face of that judgment I am disposed to believe that the Engineer must frequently look to such waters when subjected to domestic filtration as the means of supply wherever sewage contamination prevents the use of rivers or shallow wells. As one who has taken much pains to ascertain the quantity and quality of water to be obtained from roofs, I greatly regret that so little has been said by the Rivers Pollution Commissioners to encourage its judicious collection, storage, and filtration. It is a consolation to know, however, that in the opinion of so high an authority as Dr. Angus Smith "the impurities of rain are completely removed by filtration through the soil" (*Air and Rain*), and that in the judgment of the Royal Commission on Water Supply (1869), *perfect filtration*, which is essential to the good quality of water supplied for domestic purposes, is not at present reached—from which the Engineer may gather that with advancing knowledge we may become perfect, and so secure purity.

There are localities in all countries where, in the absence of river and pure well water, *rain water from roofs or prepared impermeable surfaces* constitutes the only source of supply for separate dwellings. In providing potable water in such cases, it is the duty of the Engineer to do his best to remove the objections of the Chemist, and this he may do by the means to be taken—first, in collecting, next in storing, and lastly in filtering the water which he has collected and stored.

I hold the opinion that, in fact, there exists no more certain source of a pure and sufficient supply than that of properly collected and properly filtered rain water, which is with care to be secured by all persons alike (see Section LXIV.). There is no cleaner surface from which to collect rain than that of roofs formed of slates and the harder description of tiles, if pains are taken to prevent the growth of vegetation, the collection of decaying leaves, and the deposit of the excrements of birds.

To correct any impurity that may find its way from roofs into the underground tanks, used for storage, filtration must be resorted to. I have contrived two species of filters to effect this purpose; the first is placed in the underground tank, and appended to the bottom of the suction pipe of the house pump. It extracts from the water, before it is lifted into the house, any solid matters that may be in suspension. But as it is always *under water*, it serves to *clarify*, without chemically purifying the supply that passes through it, but this clarification it performs most effectually. (See Drawing VIII.)

The second filter is placed inside the dwelling. It is called the "Self-supplying Oxidizing Filter," and by it that chemical purification, not aimed at in the first filter, is performed. The oxidation is effected by the perfect aëration of the filtering material—which may be of any approved kind—through which every drop of water used in the kitchen, bed rooms, and elsewhere, must pass as it descends from the service cistern for use. As water is withdrawn from this filter, fresh water comes in automatically by the action of a ball tap, and this fresh water immediately passes through the aërated material into the lower chamber forming the supply cistern for the whole house. (See Drawing VIII.) The filtering material I use consists of very finely broken stoneware potsherds and animal charcoal. I claim no special merit for these contrivances, and do not present them to you with any commendation of my own. Though invaluable as a safeguard, this two-fold filtration is not always necessary. On submitting to Dr. Benjamin Paul, for analysis, twelve samples of water, *i.e.*, four samples of the rain water taken out of the underground tank as it came from the roofs, with an equal number of the same water once filtered, and the like twice filtered, he found that the rain water itself before filtration was so pure as to be perfectly potable. The samples were transmitted to Dr. Paul as they were collected for four consecutive weeks in December, 1875, and January, 1876.

Dr. Paul's report bears out so completely my own estimation of the valuable character of roof water, that I give it *verbatim*.

"In reference to the results obtained by the analysis of the twelve samples of water reported upon to you last week, I beg to offer the following remarks. As regards total solid contents existing in solution in these samples of water, the amount ranged from 2·8 to 9·2 parts in 100,000 parts of water corresponding to 2 to 6½ grains per gallon. This solid substance, obtained by evaporating the water and drying the residue at steam heat, consisted partly of lime salts dissolved by the water from surfaces with which it had come into contact; partly, also, of substances washed out of the air, and partly of water retained by the residue at the temperature of 212° F. That portion of the total residue which resisted the action of a red heat ranged in the several samples from 0·2 to 6·4 parts in the 100,000 parts of water, and this portion consisted of earthy saline substances, such as are always present in solution to some extent in all kinds of natural water. The remaining portion of the solid residue that was volatilized by heat consisted of organic substance, water with minute quantities of ammonia salts and nitric or nitrous acids, and the amount of this portion ranged from 2·0 to 4·0 parts for the 100,000 parts of water corresponding to about 1½ to 2¾ grains per gallon. It is within the amount of this latter portion of the contents of the water that the presence of any deleterious material is to be sought for; and since such deleterious material cannot amount to more than a fraction of the quantities comprised within these limits, it is evident from these data alone that all the samples of water were of a high degree of purity. This conclusion is further confirmed by the results obtained in testing the water for the purpose of ascertaining the amount of ammonia and of organic nitrogen present in it. The amount of ammonia ranged from 0·0015 to 0·034 part in 100,000 parts of water. The amount of organic nitrogen ranged from 0·011 to 0·022 part in the 100,000 parts of water. Both these results are indicative of the very high degree of purity of the water, and the amount of organic nitrogen especially indicates the absence of any such organic contamination as would be prejudicial either on account of its quantity or nature, taking into account the source of the water.

"As regards this latter point, the samples of water compare well with those instanced by the Rivers Pollution Commissioners as being samples of unpolluted water obtained from springs and deep wells in various localities, as may be seen from the following comparison of the average character of unpolluted water from these and other sources, as given in the report of the Commission, with the results obtained by the analysis of the twelve samples now referred to.

	Ammonia	Organic nitrogen
Rain water	·029	·015
Upland surface waters....	·002	·032
Deep well water	·012	·018
Spring water...	·001	·013
Average of 12 samples...	·009	·015

"From the results obtained by the examination of the twelve samples of water received from you, and from comparison of those results with the characters assigned by the Royal Commissioners to unpolluted water, I am decidedly of opinion that although their objection to rain water as being 'often polluted to a dangerous extent by excrementitious matters,' and 'rarely of sufficiently good quality to be employed for dietetic purposes with safety,' (see Report, p. 24) is unquestionably well founded, so far as it applies to rain water liable to pollution from storage in underground tanks, it is by no means a sufficient reason for abandoning the use of rain water for such purposes, provided adequate precautions be taken to prevent the water from being contaminated before it is used.

"The danger of such contamination lies mainly in access of surface drainage to the underground tanks in which the water is stored; and the objectionable character of the eight samples of 'rain water stored for domestic use,' referred to by the Royal Commissioners (see Report, p. 29), as furnishing evidence in support of their objection to rain water, appears to have originated from the want of proper safeguards against infiltration of drainage water into the tanks; for while rain water rarely contains, on the average, more than three or four parts of total solid contents in the 100,000 parts, the average in the eight samples mentioned by the Royal Commissioners is as much as 24 parts in 100,000 of water, and in one instance rises to more than 126 parts in 100,000. Such a result, however, is merely accidental, and by no means a necessary consequence even of the storage of rain water. It is, I imagine, a result that can be avoided; and since rain water in itself is very often quite unobjectionable for domestic use, there is in regard to its use for such purposes room for establishing a very large practical exception to the general principle of condemnation laid down by the Royal Commissioners.

"As regards the more immediate object for which the analysis of these twelve samples of water was undertaken, I am unable to furnish you with any opinion, for the unexpected purity of the water as first collected is so great that filtration has no effect upon it beyond

removing small quantities of suspended impurity—dust, soot, &c.,—and rendering the water bright and clear."

XXXVI.—Of so-called "Suspicious Waters"—the Waters of Under-drainage. In some districts wide areas of wet land have been under-drained; and as winters succeed each other, a supply of water, varying from 30,000 to 70,000 gallons per acre,* is annually discharged. Of this water the Rivers Pollution Commissioners go so far as to say, after the qualified condemnation I have quoted, that "the supply of such water can be very easily and safely accomplished wherever the subsoil drainage of pasture and meadow land is capable of collection in storage reservoirs of the moderate capacity sufficient for the needs of a hamlet or small village." "The drainage from manured arable land is, as we have stated, by no means a desirable source of potable water, and must be unreservedly condemned, if human excrements are used as manure. But with that exception the drainage water of even arable land is preferable to that from polluted shallow wells which are at present the usual source of the water supply in country places."

By the water of under-drainage (as I use the term) is meant the water extracted from the subsoil by under-drains laid in it at depths varying from three to six feet or more. This water forms a new source of available supply for villages and hamlets, because the rain which fell upon retentive or saturated soils, before they were under-drained, was either absorbed and held by them to be evaporated and lost as vapour in the air, or it was thrown off the surface and lost as water in times of flood or excess.

The same lands when drained absorb the rain, instead of allowing it to be evaporated or thrown off the surface. It infiltrates to the level of the under-drains, and passes out of the subsoil gradually by the drains to the outfalls, leaving behind in the soil only just enough water to satisfy its naturally retentive properties. Comparing this water, which has had the benefit of filtering through four feet or so of earth, with that which is now generally used in rural districts, and which is often obtained off roads and land surfaces when river and well waters fail, and are known to be decidedly deleterious, it is impossible to deny that the substitution of one for the other would be a very great advantage.

In many cases the water discharged from the under-drains of land may be collected and "refiltered" through natural soil without any great increase of expense and with every probability of completely

* *The Supply of Water to Villages and Farms*, and *Storage of Water*. By the Author.

oxidizing and rendering harmless any organic matter that may remain in it.

XXXVII.—Of so-called "Suspicious Waters."—Waters to be collected from Cultivated Surfaces. This last expedient (filtration through natural soil), may also be applied beneficially to waters collected from the surface of cultivated lands where human excrements are not used as manure. When investigated by the Engineer it will often be found that the water of streams running through private estates, and made up of surface waters from cultivated lands, may be diverted out of their courses on to the surface of small areas of land near at hand, which, if purposely prepared by proper under-drainage, will absorb and discharge such water after freeing it from those impurities which it gathers as it passes over the contributing surfaces.

XXXVIII. — Of so-called "Dangerous Waters."—Rivers, Streams, and Running Waters. Passing from the "suspicious waters," which filtration may render safe, to the "dangerous waters," which the Rivers Pollution Commissioners have so decidedly condemned, I will not detain you by any justification of the use of rivers and streams into which excrementitious refuse has been discharged, further than to bring under notice the views of the Water Supply Commissioners who were appointed to enquire "into the means of obtaining additional supplies of unpolluted and wholesome water for the metropolis and other large towns," which contrasts with singular force with the opinions of the Rivers Pollution Commissioners.

The Water Supply Commission (1869), when speaking of the rivers Thames and Lee, said that "supplemented, if necessary, by works for storing the flood waters, and by the water obtainable from the chalk and greensand, those rivers will furnish a supply sufficient for any probable increase of the metropolitan population, and with perfect filtration and efficient measures for excluding the sewage and other pollutions, water taken from them will be perfectly wholesome and of suitable quality for the supply of the metropolis." Now, considering that the Water Supply Commission consisted of the present President of Her Majesty's Privy Council (the Duke of Richmond); the present President of the Institution of Civil Engineers (Mr. T. E. Harrison); the late President of the Geological Society and present Professor of Geology at Oxford (Mr. J. Prestwich); as well as the Chairman of the Metropolitan Board of Works (Sir J. Thwaites),

it is hardly possible to quote the views of men more worthy of consideration. It is beyond the power of Sanitary Engineers to reconcile these views in any tangible manner.

XXXIX.—Of so-called "Dangerous Waters."—Shallow Well Waters. You will remember that the Rivers Pollution Commissioners spoke of water obtained from shallow wells as less fit for human consumption and more dangerous to the public health than the water of sewage-polluted rivers.

Of 412 wells which they examined, there were very few yielding a supply of a sufficiently pure character. I believe, however, that if the matter were further and more closely examined, it would be found that shallow wells in towns and villages are not unfrequently rendered impure by organic matter falling directly down to the water in the well from the surface, as well as by sewage passing through the surrounding soil. To avoid the possibility of foul water descending thus directly down into wells, a practical remedy has been proposed which might in many cases be usefully adapted to wells in rural villages, where they are sunk in situations so far distant from dwellings as to command underground water naturally pure. The remedy is the use of the Abyssinian tube pump or the adoption of the plan of doming over the water in a well just above its standing level —where the water lies within the reach of an ordinary lift pump— and to fill the well up with soil from dome to surface. Before filling in the soil, a pipe should be fixed in the dome reaching to within a few inches of the bottom of the water, and extending upwards to the surface. Upon the top of this the pump is to be fixed. Such a pump would partake very much of the character of the Abyssinian pump. I refer to this arrangement—which was suggested to me by an article in *Chambers's Journal*—not to convey any opinion of my own with respect to it, for I have not yet tried it, but simply to show that practical suggestions will not be wanting to relieve even shallow well water from wholesale condemnation when improved sanitary works in towns and villages have reduced to a minimum the chances of sewage contamination by percolation through the soil.

XL.—Hard and Soft Water. The time before me will not allow of any explanation of the comparative advantages of soft and hard water. Moreover, the subject is hardly one for the judgment of the Engineer. I must be content with appending a full description of Dr. Clarke's process for the softening of water by lime, which has

now stood the test of a quarter of a century, and may be usefully applied in many cases (see Appendix G.).

The Rivers Pollution Commissioners put the several waters derived from various sources in the following order:—

1. Rain water (softest).
2. Upland surface water.
3. Surface water from cultivated land.
4. Polluted river water.
5. Spring water.
6. Deep well water.
7. Shallow well water (hardest).

Water at or below six degrees of hardness is considered "soft,"—above that number of degrees, "hard water." "Hardness" implies one grain of bicarbonate or sulphate of lime in a gallon of water.

XLI.—Further Investigation into the Water Question imperatively required. With these general observations on the sources of water supply I will leave the question for the present. They arise from the chemist's view of the matter, which has now been exhausted. Having for many years advocated the storage of surplus waters for the use of small communities, and having done my best to point out the very liberal supply of unexceptionably pure water with which Providence has blessed our country, I cannot resist repeating the earnest desire I entertain, that under the auspices of Government a careful enquiry by competent men with practical minds may be instituted to determine how far the natural resources of different localities may be made available in those localities. The country requires instructions *how* to develop local capabilties so as not to rest upon State interposition. It is most difficult for the student in sanitary science to understand the present views of the ruling authorities of this country in relation to the question of water supply. The elaborate reports of the several Commissions appointed to enquire into the polluted condition of our rivers and the disposal of sewage appear to be entirely put on one side, although their recommendations, with respect to the establishment of standards of condition of liquids discharged into running waters, were supported by the opinions of the leading Chemists of Europe. Astounding as it may appear, the fact is nevertheless true that at this moment when the whole population of the country is clamouring for pure water several chemical processes for the treatment of sewage, which have been positively condemned by the Commission to which I have referred, are in action, with the concurrence of the Government,

in the valleys of the Thames and Lee *above the intakes* of the Companies supplying the metropolis with water! (See Section XCV.).

It would really seem that although the whole country is agreed that the death-rate is sensibly increased by neglecting the condition of our streams, no Government is strong enough to revert to the laws of the Egyptians and say "Thou shalt not defile our rivers." Loss of life would appear to be preferred to loss of trade, and although the preference may be reconciled with *individual* interest, it is entirely opposed to the *national* weal.

DIVISION III.

THE DWELLING.

XLII.—Definition of the Term "Dwelling." Being about to apply practically the observations which I have made on "*Air*" and "*Water*" to the work of the Sanitary Engineer in the dwelling, and then to the town and village which are the congregations of dwellings, I should preface what I have to say by stating that the term "dwelling" includes every structure inhabited by human beings, either constantly or temporarily, whether it be the palace, the mansion, the barracks, the depôt, the hospital, the school, the factory, or the cottage; and wherever situated, whether in town, village, park, or paddock.

XLIII.—The Site. The Architect, rather than the Engineer, is generally the person consulted upon the sites of dwellings when they are erected outside towns and villages, although there is no single object upon which the services of the Sanitary Engineer could be more usefully employed. In towns and villages the sites of additional or substituted dwellings are generally fixed irrespective of the advice of any one.

In the case of isolated dwellings, however, where selection can be made, it is unnecessary to point out that adverse conditions in the site may render the best designed and best built structure unhealthy, for as stated by Bacon, whose wisdom condescended to such social questions, "he who builds a fair house upon an ill-seat committeth himself to prison," to which he added the quaint but true remark that he did "not reckon it an ill-seat only where the air is unwholesome, but likewise where the air is unequal."

Aspect and shelter have each their bearing upon salubrity and equality of temperature, but neither the one nor the other has an influence so great as the condition of the soil beneath and surrounding the dwelling. Dryness of site is essential to both these

advantages, and, as already stated, the Engineer has the power by appropriate drainage to render a subsoil, which is naturally wet and polluted, both dry and wholesome.

XLIV.—Drainage of Site, in Contradistinction to Sewerage, Essential to Health. With the facts before us already quoted from Dr. Buchanan's Report,* showing the remarkable manner in which a decrease in deaths from phthisis, or pulmonary consumption, had followed the drying of the soil, and the concurrence generally expressed by the Medical Profession in Professor Pettenkofer's views on the effects of the rise and fall of ground water, there can be no doubt that, where the standing water in the soil does not naturally lie at such a depth below the surface as to be beyond the power of injury, the Engineer should effect that object artificially by under-drainage, and thus help in reducing the death-rate.

I select consumptive disease to illustrate prominently the sanitary effect of drying the soil, because it is quite sufficient of itself to justify all that can be said in favor of the perfect under-drainage, in contradistinction to the sewerage, of human dwellings, with which it is often confounded.

The proportion of the entire death-rate of England and Wales which is due to consumption alone has been shown by the Registrar General to be about one-ninth.

Between the years 1867 and 1872 the deaths *per million* living in England and Wales were as follows:—

	1867	1868	1869	1870	1871	1872
All causes.....	21,983	22,200	22,626	22,947	22,622	21,340
Registered Phthisis (Consumption)	2,595	2,395	2,409	2,435	2,364	2,297

In proof of the beneficial effect of drying the soil, Mr. Simon, in his Report of the 31st of March, 1868, says the death-rates by phthisis in the 15 undermentioned towns had *fallen* per cent. as follows, after the "drainage" of the ground.

Salisbury	49	Leicester	32	Dover.....	20
Ely	47	Macclesfield	31	Warwick	19
Rugby...	43	Newport (Monmouth)...	32	Croydon...	17
Banbury	41	Cheltenham	26	Cardiff ...	17
Worthing	36	Bristol	22	Merthyr...	11

XLV.—Definitions of the Terms "Drain" and "Sewer." I shall not have a better opportunity than I now have, when speaking

* Ninth Report of the Medical Officer of the Privy Council.

of *drying the soil*, of explaining the difference between a drain and a sewer, which the Public Health Act, 1875, 28 & 39 Vict., Cap. 55, has done much to confuse by attempting to give an interpretation which is opposed to both literal meaning and common sense. In that Act we find that a "drain" is interpreted to be "any drain of and used for the drainage of one building only" "for the purpose of communicating therefrom with a cesspool or other like receptacle for drainage" ("drainage," I presume, means sewage) "or with a sewer into which the *drainage*" (this, I presume, also means sewage) "of two or more buildings or premises occupied by different persons is conveyed;" while a "sewer" is stated to mean "sewers and drains of every description except drains to which the word *drain*, interpreted as aforesaid, applies, and except drains vested in or under the control of any authority having the management of roads not being the local authority under the Act."

Now, the fact is, an underground "drain" means nothing more nor less than a conduit intended to draw out of the land through which it passes, the water which is in that land, and, as far as capillary attraction and natural retentiveness will permit, thus remove the wetness caused by it.

The word "drain"* is derived from the French verb "*trainer*," to draw, and the precise meaning of the original word is "a channel to draw together water by degrees"—the very reverse of the object of a "sewer," a word also derived from the French, the precise meaning of which is "a conduit for the discharge of filth." After 30 years constant practice in this branch of Engineering I may be pardoned for saying that, without under-drains to act as here explained, it is not possible to dry a damp subsoil. It has been already shown that such drying is essential to the healthy condition of all dwellings, and I now again would emphasize the point, believing that its importance cannot be over-rated. A sewer should be used simply as a conduit to discharge its filthy contents as quickly and as completely as possible, without receiving any accretion of liquid from the soil through which it passes, or allowing any part of its contents to escape into the soil.

No Act of Parliament can alter the meaning of these words, or the purpose of the works they explain, although our parliamentary draftsmen may by the perversion to which I have referred add to the confusion already existing in the public mind on sanitary legislation. It has been, in fact, the confusion existing on the question of "drains" and "sewers" that has helped to destroy

* I believe the origin of the word *drain* was the Saxon word, "drehnigean,"—a filter.

the purity of our rivers. A river is the "surface drain" of its basin, though it has in many cases been converted very improperly into a "drain-sewer" by the influx of filthy effluents from towns and districts. A river, in truth, is a channel which "draws together water by degrees" from the various tributaries, which extend to its water shed, *i.e.*, the anti-clinal ridge separating one river basin from another. It appears to me to be antagonistic to sanitary progress that such an interpretation as that contained in the Public Health Act, 1875, should have been given, for the sanitary Engineer in the exercise of his duties, must use both "drains" and "sewers" for the distinct purposes which nature and reason have indicated; and though in certain instances a sewer may serve both its own purpose and that of a drain, without any injurious effect, still the time is not far distant when it will be generally acknowledged that a drain can never properly be used as a sewer, nor a sewer as a drain, but that there should be separate conduits for each purpose.

There cannot be a doubt that, while drains should draw into them as much water as possible, sewers ought to be thoroughly water-tight, for, as already stated, if they are not so, the same openings which admit the subsoil water will allow the sewage to escape into the subsoil, and thus create in the proximity of the dwelling one of the most formidable nuisances to which it can be subjected. To low and flat parts of inhabited districts this remark will particularly apply, though I may state that I have also known the basements of houses in the higher parts of towns rendered foul by the passage of the contents of the sewer into them through the joints of the pipes and the surrounding soil on occasions of excessive rainfall. This evil, we are told, has been experienced in the lower parts of Worthing, and at Cambridge. *(Corfield's Digest of Facts, relating to the treatment and utilization of Sewage).*

In spite of these facts, which must come home to every Engineer, it is difficult, at the present moment, to say, after reading the interpretation clause of the Public Health Act, whether such a work as a "drain" in its true meaning is recognized by the Government, and whether those who have to dispense the law acknowledge the necessity of drainage—in contradistinction to sewerage—at all. What the Public Health Act interprets as a "drain" is really nothing more nor less than a branch sewer to "communicate" (connect) the private dwelling with the common public sewer, or with any private receptacle for sewage which may be used in the absence of a public sewer.

I regret that it should have been stated in any official document,

such as the *Suggestions upon Sewerage and Drainage*, prepared by Mr. Rawlinson, that sewers and drains should, when practicable, "*be made to act as land drains*," for, as I have already said, I can conceive nothing more likely to command the reprehension of the next generation than the confusion such terms will lead to. Already Dr. Corfield in his *Digest of Facts* has adopted the compound term "Drain-sewers" Without denying that there may be certain towns so physically circumstanced as to allow sewers to be designedly constructed to serve the two purposes of sewers and drains without unfavorably prejudicing their future sanitary condition, I can only admit that one description of conduit deserves the title of "drain-sewer" and that is a double conduit consisting of a water-tight sewer with an open-jointed or perforated drain attached to it. Such a double conduit is made by Messrs. Brooks, of Huddersfield. There is, however, considerable difficulty in adopting this double conduit, owing to the incapability of making the joint of the sewer water-tight while leaving the drain continuously open. Moreover, there is no necessity for adopting it, for the Engineer finds in practice that the same trench that contains the sewer will admit of a detached drain being laid in it also. Both then act as independent conduits without detracting from the utility of each other.

XLVI.—Capacities of Different Soils for Retention of Water, and the Influence of Wet Soils upon the Sanitary Condition of Cellars and Basements. All soils in positions to affect dwellings may be divided into three classes; first, those that are comparatively impervious, and will therefore resist absorption; second, those that are pervious and retentive, and absorb and give off water slowly; and last, those that are pervious and free, and absorb and give off water more rapidly.

In the first we include exposed rocks; in the second, clays of various qualities and degrees of density; and in the last, the sands, gravels, chalk, and mixed soils of various degrees of porosity.

In the absence of either natural or artificial drainage, all soils—retentive and free—hold water according to the interstitial spaces they contain. Without distinction all soils thus filled with water instead of air, impart dampness to the walls with which they are in contact, while the "ground air" which arises from them in summer becomes injurious to health from its being more or less impregnated with putrescible matter.

"Impermeable" granites and marbles of the greatest possible density hold about a pint of water per cubic yard, while a loose sand

will contain from 40 to 50 gallons per cubic yard. Ordinary red sandstone will hold 27 gallons per cubic yard. My own experiments (see *Land Drainage and Drainage Systems*) showed that the clay of the London clay formation will absorb nearly 50 per cent. of its own weight when dry, that the Oxford clay will absorb 30 per cent., and that the lias will absorb nearly the same quantity as the latter.

The power of soils to hold water and maintain a wet condition, differs as greatly as their power of absorption. In 1856-7, I had some very careful observations made of the discharge of the under-drains of a free soil, consisting principally of chalk mixed with clay, gravel and sand, and of an adjacent clay soil of the gault of the cretaceous formation, which showed this difference to exist in a remarkable degree, the retentive power of the clay being $2\frac{3}{4}$ times greater than that of the mixed soil.

	Rainfall. Gals. per acre.	Discharge of under-drains. Gallons per acre. Free soil.	Clay.
Oct.	37,215	12,910	Nil.
Nov.	36,872	27,000	330
Dec.	27,935	30,135	5,825
Jan.	52,775	43,855	31,805
Feb.	4,343	27,360	9,060
March	18,547	8,415	3,310
April	32,566	6,698	6,183
May	16,967	4,177	3,418
Totals per acre	227,220	160,550	59,931
Differences between rainfall and discharge		66,670	167,289
		227,220	227,220

In the case of the free soil, the drains were placed in selected (irregular) places, at wide intervals, while those in the clay followed parallel lines 25 feet apart.

Those who would know the true effect of saturated soil upon under-ground cellars used as human dwellings should study the published reports of Dr. Duncan, of Liverpool, and Dr. Aldis, of Whitechapel, as well as those of Dr. Buchanan, Dr. Thorne Thorne, and Mr. Netten Radcliffe, addressed to the Medical Officer of the Local Government Board. Dr. Duncan, when speaking of Liverpool, pointed out that the Ward where the greatest cellar population exists is also the Ward where fever is most prevalent—one in 27 of the inhabitants having been annually attended by the dispensers. But it is unnecessary to quote such details. The statistics in existence distinctly show that disease claims as many victims from

damp and sewage-reeking floors and walls, as from any other single cause affecting the sanitary condition of the cellar population of towns. The importance therefore of the "drainage" of the sites of all dwellings will be generally admitted.

XLVII.—Capillary Attraction and Evaporation. All soils are more or less susceptible to capillary attraction. In the chalk formation, water will rise from the level of complete saturation to a very considerable height above it, while a bed of sand will be completely dry only a foot or so above the water standing in it. Wet soils of a more dense and retentive character (clays) do not give off vapour as copiously as free open soils kept wet by under-lying water; nevertheless, as long as there is any water below sufficiently near to keep them moist by attraction, evaporation will continue, and in the end the amount of vapour given off from them will be much greater than in the case of free soils under similar conditions of outfall. Moreover organic substances existing in clays undergo decomposition slowly and without any diminution in the amount of carbonic acid gas evolved from them. It is for this reason that clay lands are termed *cold*, and may be considered comparatively insalubrious and therefore objectionable as the sites for dwellings.

From what has been said it may be taken as a rule that wherever ground is water-logged owing to the want of an outlet,—whether the soil be an open gravel, or a dense clay,—it is unfit for the site of human dwellings until the line of saturation—*i.e.*, the subsoil water—is lowered by drainage to such a sufficient depth as not only to reduce evaporation, but to prevent the rising of moisture by attraction up to the cellar-floors and the foundations of the dwelling.

Nevertheless, if we examine closely into the condition of inhabited districts, we find considerable areas of water-logged land on the banks of rivers covered with dwellings, regardless of the height of the subsoil water beneath; and if, further, we examine into the rate of mortality, with special reference to deaths from lung diseases, rheumatism, and heart complaints, we see that they are increased in exact proportion as wetness prevails.* (See Section XII.). It is found in all inhabited districts that those parts which have the natural advantage of a deep crust of open dry soil between the basements of dwellings, and the subterranean water level beneath, command a superior state of salubrity.

* Dr. Lenton, of Coventry, in a letter with which he has favoured me, states with respect to erysipelas:—"I can only say from my own experience that in those parts of the town built on damp clay soils, undrained, erysipelas is endemic."

When speaking thus of the advantages of a dry soil, and the evils of a wet one, it should be borne in mind that a healthy site for dwellings is indirectly dependent upon the condition of neighbouring lands. A town, for instance, may be admirably well sewered, and a mansion may have the best devised internal arrangements, and they may both be less healthy than other towns and dwellings not so carefully treated, owing to the existence of outside influences, such as the low marshy meadows existing in proximity to Oxford, or the saturated though picturesque grounds which often surround superior mansions built by the sides of rivers.

"*Qui legitis flores et humi nascentia fragra,*
Frigidus, o pueri, fugite hinc, latet anguis in herba."
Virg.: Ecl. iii., 92.

XLVIII.—Mode of Under-Drainage Required to Dry the Sites of Dwellings. The method of under-drainage necessary to lower the water level in wet lands to a proper depth will vary with the character of the subsoil. In water-logged free soils a single drain will often lower at very little cost the water level of a wide area. This effect has been produced by so-called "drain-sewers," which have lowered the water in wells as well as in the soil, and have been known to cause settlements in houses, as at Norwich, by the removal or displacement of sand with the water beneath their foundations. It may be taken, as a rule, that in free soils no advantage is gained by multiplying drains beyond the minimum number that will lower the subsoil water, and that they should be as far removed from buildings as possible.

In clay soils numerous drains are requisite to overpower the retentive properties which such soils possess. The greater the number the better will that purpose be fulfilled.

All drains should be made secure against the entry of the roots of trees, and the accumulation of peroxide of iron, and other impediments; this will be done by carefully jointing the pipes with tarred gaskin and Portland cement when passing through any places subject to such obstructions.

Though it is desirable to avoid placing drains under any buildings, still they are sometimes essential to the perfect drainage of the sites of dwellings built on clay soils. When adopted, care must be taken to produce, by the complete aëration of the subsoil, that uniform disintegration which will prevent contraction and expansion under different conditions of the atmosphere, so as to avoid any injurious effect upon the superstructure.

I need hardly say that when speaking of placing "drains" under dwellings, I am not speaking of "sewers."

XLIX.—Concrete Floors and Areas to Basements, and Damp Courses to Walls Essential to Healthful Dwellings. After the water level in the ground has been lowered by drainage, every care should still be taken to prevent dampness rising into the basement floors or up the walls through the foundations of the dwelling. To protect basement floors from this evil it is desirable to lay them on a bed of concrete extending over the base of the dwelling from outside wall to outside wall, as is shown upon *Drawing* I., *Fig.* 4. This will not only prevent dampness and ground air rising from the underlying soil into the inhabited apartments of the dwelling, but it will also prevent any liquid refuse from sinking into the ground beneath to aggravate the pernicious character of the ground air. To prevent moisture from rising up the walls of dwellings it is now a general practice to build them on a foundation of concrete, and to have damp courses consisting of an impervious layer of cement and slate, or of asphalte, between the courses of bricks or layers of stonework; and the bed of concrete under the basement floors should be to the cellars and rooms above them what the damp course is to the walls.

All dwellings possessing basement floors under the level of the natural surface of the ground, should have areas between the surrounding ground and their walls, with proper sewers and drains laid beneath the areas to discharge liquid refuse and any surface water, which would otherwise collect in the areas. (See same *Drawing*).

In clay soils, cellars and basement floors should be avoided altogether, for the retentive properties of clays will invariably cause dampness—and therefore coldness—within the dwelling, which no under-drainage can effectually overcome. Dwellings erected on clay soils ought, in fact, as a rule, to be well raised above the ground-surface, with a free ventilation between the surface and the ground floor of the dwelling.

L.—Dripping Roofs. Dripping roofs are a very common cause of dampness in the soil in immediate contact with the walls of dwellings. Many a house without a basement floor, and otherwise dry and healthy, is rendered quite unfit for the habitation of the aged and the infirm from this cause alone. It will be frequently

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Drawing I.

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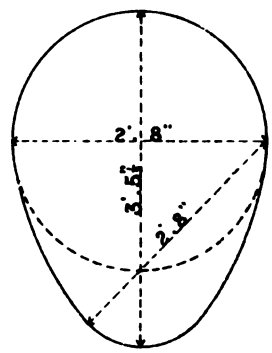
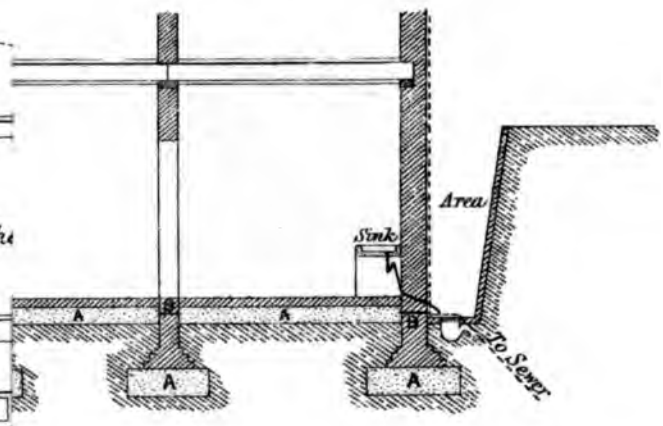


1. 4.

FLOOR.

to prevent Damp.



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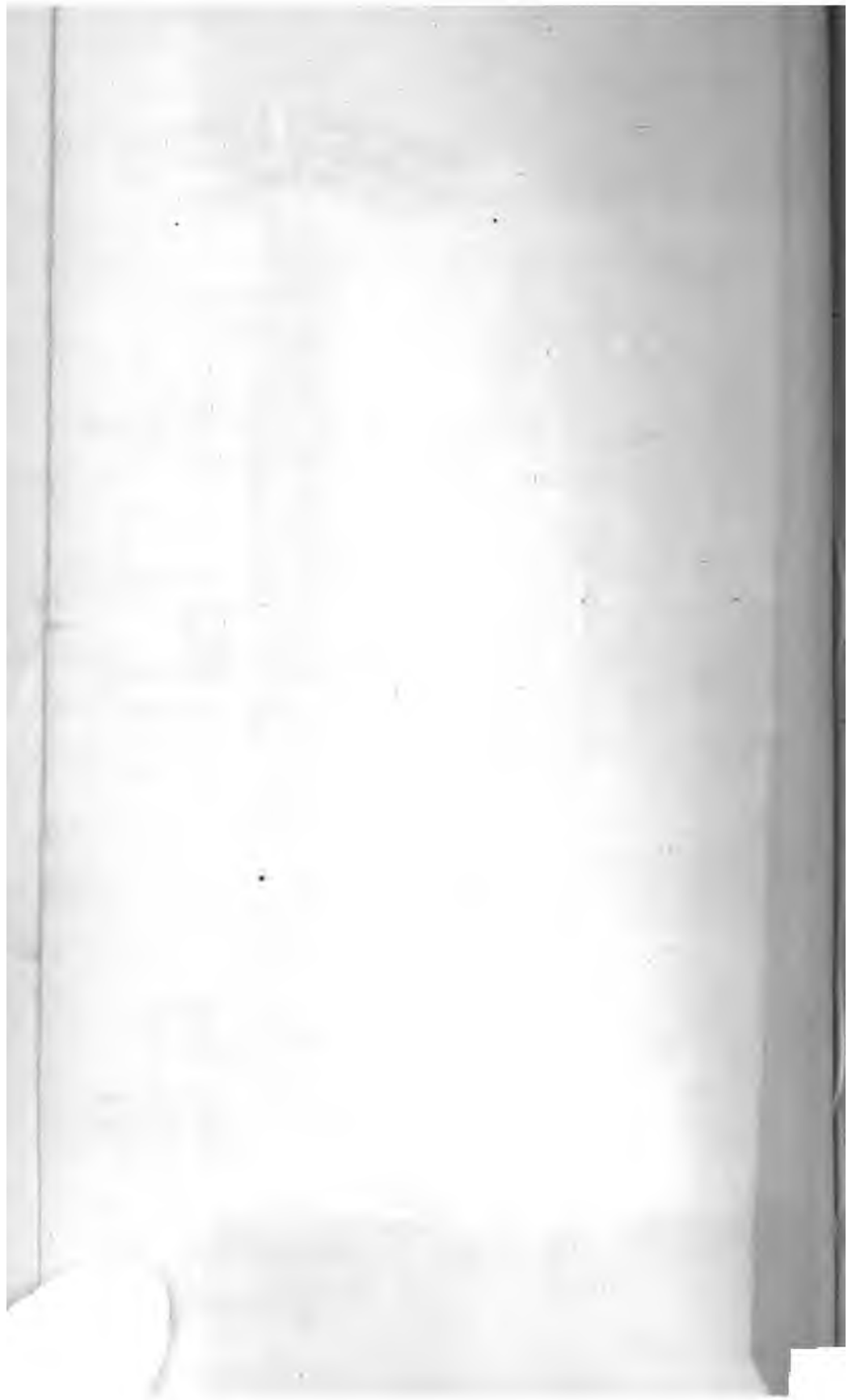

observed that the rain falling on the roofs of country mansions is allowed to drip upon and soak into the ground adjacent to their walls, owing to the absence of proper eave-troughs, down pipes, and water-tight outlets, and if we examine the dwellings in the majority of our country towns and villages it will be found that the same condition prevails with them even in a greater degree. It is in the absence of precautionary measures to secure a healthy base to the dwelling that "dry" rot—which owes its name rather to the effect produced than to the cause—takes root. This much dreaded enemy is generated in a damp, close, and dark atmosphere, though when once in existence it seems to rise with extraordinary rapidity from its bed, and to spread vigorously through timber and walls in all situations, dry or damp, light or dark.

THE SEWERAGE OF THE DWELLING.

I now approach the subject of the Sewerage of the Dwelling.

LI.—DEFINITION OF "SEWAGE." There exists much confusion as to the meaning of the term "sewage," which, so long as it continues, will interfere with a proper exercise of the duties of both sanitary authorities and sanitary officers. The Sewage Committee of the British Association declared that the term sewage applied to any refuse from human habitation that may affect the public health (*First Report of the Sewage Committee of the British Association*, 1869), and this broad acceptation of the term may be fully justified.*

When considering the work of the Engineer it will be better to divide sewage into two parts, 1st—the refuse of which the medium of removal is water; and 2nd—the solid refuse and garbage conveyed by hand to the ash-pit or dust-bin, and the excretal contents of the privy or outside closet, the removal of which may be effected by mixture with earth, ashes, or other dry material.

The first, or liquid refuse, will be discharged by the sewer; the second, or solid refuse, will be removed by the scavenger.

* "Sewage is a very complex liquid; a large proportion of its most offensive matters is, of course, human excrement discharged from water-closets and privies, and also urine thrown down gully-holes. But mixed with this there is the water from kitchens containing vegetable, animal, and other refuse; and that from wash-houses containing soap and the animal matters from soiled linen. There is also the drainage from stables and cow-houses, and that from slaughter-houses containing animal and vegetable offal. In cases where privies and cesspools are used instead of water-closets, or these are not connected with the sewers, there is still a large proportion of human refuse in the form of chamber slops and urine. In fact, sewage cannot be looked upon as composed solely of human excrement diluted with water, but as water mixed with a vast variety of matters, some held in suspension, some in solution."—*Rivers Pollution Commissioners.*

LII.—The Mode of Disposing of the Liquid Refuse must be Determined Before Laying Out the External Sewers of Dwellings. In order to lay out the external sewerage of the dwelling it is absolutely necessary to determine beforehand the mode of disposing of the liquid refuse.

In urban or rural districts, where an available system of sewers already exists, the liquid refuse of all dwellings within those districts should be discharged into the nearest "common sewer" by a private communicating sewer—called in the Public Health Act, 1875, a "drain"—(Clause 21 *et seq.*, 38 & 39 Vict., Cap. 55). The mode of disposal will then be left to the sanitary authority of the district, and the owner of the dwelling will be thus relieved of all difficulty on that question. In such a case the direction of the communicating sewer will depend upon whether it follows a course of its own (see *Drawing* II.), or conforms to a combined arrangement designed to collect the liquid refuse from the backs of several neighbouring dwellings, so as to avoid the passage of sewers under any inhabited building. In thickly crowded towns this cannot be avoided altogether, though much may be done by combined back arrangements in the way suggested by Mr. Rawlinson, and shown on *Drawing* III.

There is considerable difficulty in dealing with sewage at all times, but the difficulty is often much increased in isolated dwellings by personal considerations which are disregarded in combined works. Isolation does not necessarily mean exemption from statutable obligations.

LIII.—On Present Legal Obligations in Relation to the Liquid Refuse from Isolated Dwellings. The truth of this last remark becomes more manifest directly it is acknowledged that all liquid refuse, come from whence it may, must be cleansed and freed from polluting matters before it finds its way into the river or water-course which Nature has provided for its ultimate reception.

With the Government hesitating, under present difficulties, to protect the water supply of localities, there is much disinclination on the part of country gentlemen and occupants of isolated dwellings in rural districts to acknowledge this obligation; but it cannot be long evaded now that every village and district acknowledges a sanitary authority, and is amenable to sanitary regulations, compelling them to conform to the same law that enforces those regulations upon large communities.

ering: — THE DWELLING.

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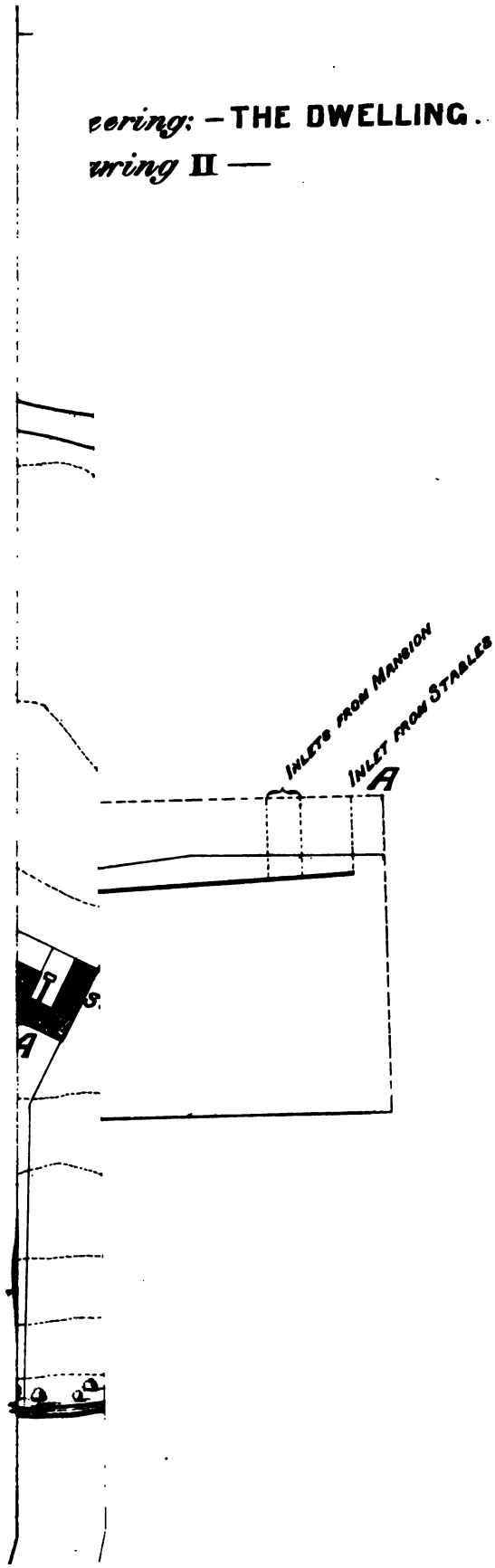
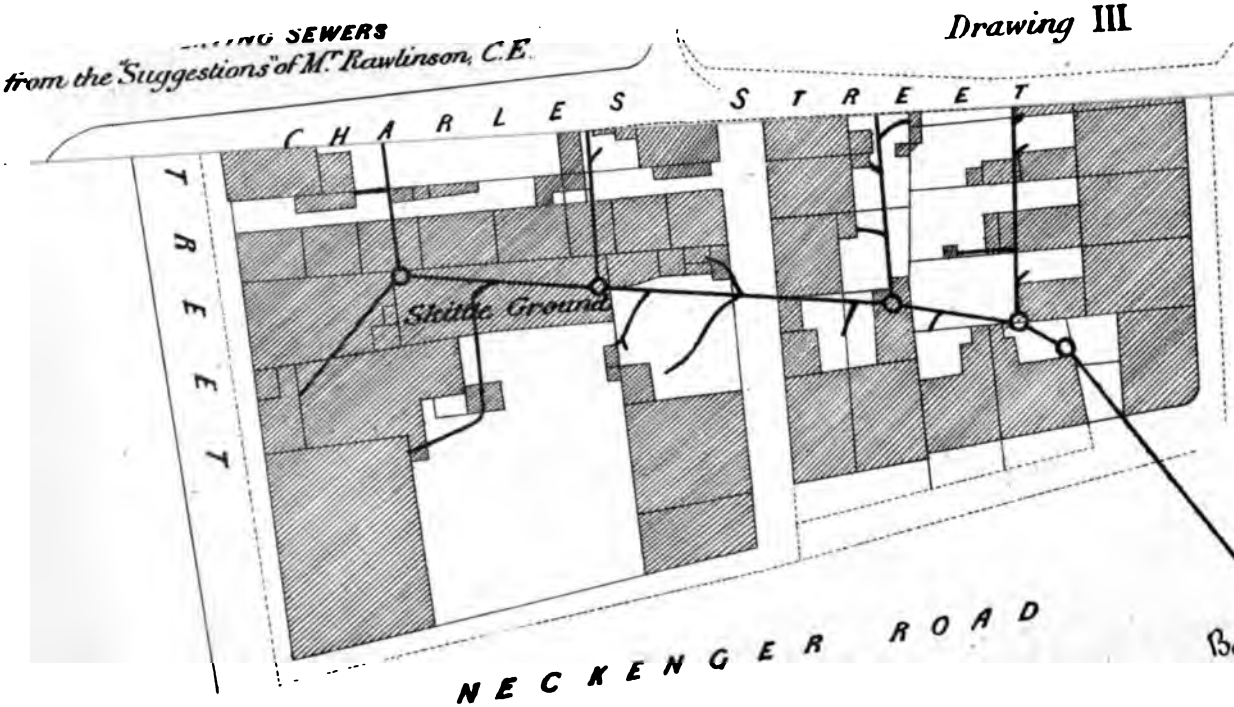


Sanitary Engineering; THE DWELL...

Drawing III

...ING SEWERS

...uced from the "Suggestions" of M.r Rawlinson, C.E.



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By the 17th clause of the Public Health Act, 1875, it is declared that "nothing in that Act shall authorize any local authority to make or use any sewer, drain, or outfall, for the purpose of conveying sewage or filthy water into any natural stream or water-course, or into any canal, pond, or lake, until such sewage or filthy water is freed from all excrementitious or other foul or noxious matter."* As soon as the obligation imposed by this clause—which, unfortunately for this country, aims negatively rather than positively at the purification of rivers—is acknowledged in rural districts, those persons occupying isolated dwellings will discontinue their present mode of discharging their liquid refuse indiscriminately into rivers. The law will in truth be enforced by inspectors of nuisances when they have been educated to their duties, and by medical officers of health who will become more vigilant as they gain experience, and who will feel bound in obedience to the general law to allow of no exemptions.

LIV.—Mechanical Deposition and Chemical Precipitation inapplicable to Isolated Dwellings. The several treatments of sewage by simple subsidence, or by mixture with lime or other ingredients to facilitate precipitation have been declared, after the most elaborate investigations by the first chemists of the age, to fail in freeing sewage of all foul and noxious matter. At the best they clarify without purifying the liquid effluent. As the time is at hand when clarification will not be regarded as the only proof of fitness required for the admission of liquids into running streams, it will be obvious that no occupant of a dwelling would be justified in adopting either subsidence or precipitation. Moreover, chemical treatment is invariably attended with very considerable expense, which is not recovered in the value of the product, and this loss, which a community may be content to suffer when there are many contributors to it, will always be resisted by single individuals. Even the clarification of the liquid refuse of a dwelling can only be maintained by labourers and servants, who at any moment might fail in producing the desired effect, and subject the occupant to the penalties set forth in the 69th Section of the Public Health Act, 1875. I am led to lay stress on this point because every day's experience is showing

* By the Rivers Pollution Prevention Act (39 & 40 Vic., c. 75), which has become law during the revision of these lectures, it is laid down that no sewage or noxious matter shall be discharged into a river or water-course until it has been freed of its polluting ingredients by *the best practicable and available means*.

that wherever a constancy of effect is of the first importance, little dependence can be placed on manual service.

LV.—Modes of treating Sewage available for Isolated Dwellings. By reading the interpretation clause of the Public Health Act (see Section XLV.), it will be seen that the Legislature has not helped in removing the difficulties of this important branch of the sewage question, for it contemplates that the liquid refuse of isolated dwellings may be discharged into some *cesspool or other like receptacle* (when not received into a common sewer), where it would be subjected to such treatment as would free the occupants of liability to penalties for nuisance or river pollution. What that treatment shall be, under the various conditions which will arise, has been left to those who are immediately concerned. The question, in fact, has been studiously avoided up to this time by all parties alike, and the disposition of individuals to deal with it has, therefore, gradually become less. Can this be wondered at when all practical minds regard "cesspools" as evils of the worst order?

If the sewage be taken to a considerable distance from the dwelling to a "cesspool," sumpt, or other like receptacle purposely made to allow the liquid to escape out of it into a porous soil, such as the chalk, the red sandstone, or one of the free oolitic beds, the sewage will probably soak away down to the subterranean water level at whatever depth it may be. If the depth be great, no mischief whatever may follow.

If, on the contrary, the water level be near the surface, then the cesspool and its unseen outpourings—though relieving the occupier of the dwelling of considerable trouble for a time—will remain liable to all the objections to which common privy-cesspits are admittedly subject. The "dumb" wells, which the larger cesspools become, have been adopted in a great number of places where the sanitary authorities of urban and rural districts have been unable or unwilling to cope with the disposal of the sewage of their districts; and wherever, as I have said, the ground water is shallow, the creation of a concentrated evil of the worst description has been the consequence. In instances where the subsoil is of a character not to absorb the sewage—such as a clay soil—as it has escaped from the cesspool, the occupier has been compelled to lift it to the surface, and distribute it by hand or hose over grass, arable, or garden land near at hand, or cast it away to a distance. This treatment is subject, however, to the irregularity attending all manual work, and generally results in a nuisance.

Wherever the grounds attached to dwellings—I refer to country mansions, and large institutions—are sufficiently wide in area, and possess surface capabilities to allow of the application of the sewage direct to *land*, as indicated by *Drawing* II. without the same dependence upon personal attention as in the treatment to which I have just referred, such a disposal will be altogether free from objection,—the primary condition essential to success being that the whole liquid dealt with shall percolate through a sufficient quantity and depth of soil to ensure its ultimate discharge in a cleansed condition. To ensure this, natural or artificial under-drainage of the land is essential whether the sewage be applied by way of surface irrigation or intermittent downward filtration, and clay soils should, as a rule, be avoided, though with great care they may be made available.

The superficial extent of land which it may be desirable to appropriate to the purification of sewage discharged from private dwellings will depend upon the character of the soil, the area at command and other local circumstances. With suitable soils which have been rendered uniformly percolative, and occupy a favourable position in relation to outfall, &c., the quantity of land utilized may be increased or reduced, and wide surface irrigation or intermittent downward filtration adopted just as it may be found expedient.

In Division V., to be devoted to the disposal of sewage, I shall explain both the process of surface irrigation as practised for many years, and that of intermittent downward filtration as more recently brought into notice.

In the meantime I may state that Dr. Edward Frankland, after making numerous laboratory experiments, declared as the result of his investigation, that the sewage of 3,300, or say 3,000, persons might be cleansed by intermittent filtration through one acre of suitable land drained six feet deep, but that the process would. be thought, be open to certain objections. My long connection with agricultural works of all kinds enabled me to appreciate Dr. Frankland's theory. I suggested as the means of overcoming the objections anticipated, and in order to secure an undoubted permanency of effect and continued freedom from everything like nuisance, that instead of using the same land for filtration one year after another, it should be used every third year, so as to give two years' rest. It is true that this rotation necessitates the use of three acres instead of one for 3,300 persons, *i.e.*, one acre for 1,100 persons; but the increase of quantity still leaves the process the simplest and cheapest mode of purifying sewage hitherto known, and one particularly available for isolated dwellings and institutions.

Practice following this suggestion has shown that if the area of land at command be limited, any quantity not less in proportion than one acre for 1,000 persons will be sufficient for the perfect cleansing of the liquid refuse discharged, while some return in the shape of vegetables from the land so used may be obtained. If, however, the surface available be unlimited, the sewage may be applied by way of surface irrigation in the proportion of one acre for 100 persons with the probability of a larger return from the vegetables grown than in the other case. Any quantity of land between these two extremes which the circumstances may prescribe, may be utilized with satisfactory effect.

Still it cannot be too well understood that such is the purifying power of natural soil where sewage percolates evenly through it, that it is not at all impossible that the area of land which would suffice to free the liquid refuse of a large mansion from all foul or noxious matter, and render it fit to be discharged into any natural stream or water-course, need be but *a very few poles* if that area is specially prepared for the purpose.

I can bring under your notice a very good illustration of what can be done in this way in the form of a letter which I received from Baron von Liebig, very shortly before his death. It tells its own tale so well that I will give the translation of it without further preface.

"Receive my best thanks for your letter of the 3rd instant, and for the paper on *Intermittent Filtration through Natural Soil*. I have read this with great pleasure and real satisfaction. You have utilised in the most effective way for the service of populations, the natural law which I laid down in my book, *The Natural Laws of Husbandry*, pp. 113 and 114. Your plan for the purification of liquid sewage and the removal of its injurious qualities, as well as the technical execution of the plan, and the use of sewage as manure, are alike excellent, and I only wish that use may be made of it in other places. In Silesia for some years past the best use has been made of your principles in the Beet-root Sugar Manufactory of Herr von Rath. In the neighbourhood where this manufactory is situated there is a want of spring water and of water generally, and this want has called forth the following arrangement. All water that has been used in the manufactory, and generally all waste or foul liquids, are discharged on to a well-drained piece of land close at hand and the filtered effluent water is collected in a well. It is pure and clear and it is again raised by a pump and used in the manufactory as fresh water. Enormous crops of grass are obtained from the piece of land which serves for filtration."

In order to avoid even the idea of nuisance, the land selected for sewage treatment should be situated at a distance of two furlongs or more from the dwelling, though in the cases of certain public asylums and hospitals much less than that distance has been found by experience to be quite sufficient.

LVI.—MEANS OF COLLECTING THE LIQUID REFUSE OF THE DWELLING, AND OF REGULATING ITS DISTRIBUTION ON LAND. The great, if not the only difficulty which is practically experienced in disposing of the sewage of isolated dwellings and institutions upon land, is that due to the irregular and comparatively small outflow, which at different times of the day is discharged from them and which has rendered it necessary to devise a means of collecting the sewage and dealing with it in fixed quantities. It was with this object that the self-acting sewage regulator was devised (see Appendix, *Drawing* II.), and as I know of no other arrangement by which this important object is accomplished I will shortly describe it. It consists of a tank or receptacle so constructed as to hold either the third, or the half, or the whole of the sewage discharged each day from the dwelling, the quantity to be collected being determined by the character and amount of sewage to be dealt with in the day. The land to receive this pre-determined quantity of sewage must be at such a level and of such a form as to allow of the whole quantity collected in the regulator being discharged upon and evenly distributed over its surface to be absorbed by the soil. The tank to hold the pre-determined quantity of sewage should be as deep as can be arranged, for the deeper it is the less will be the superficial space it will occupy, and the less chance there will be of escape of effluvium. To effect the discharge of its contents automatically, at any time of the night as well as of the day, a syphon is attached to the tank and so arranged that it comes into action directly the sewage rises to a certain height. Thus the sewage is delivered in equal quantities and at desirable intervals upon a certain quantity of land over which it distributes itself, and by which it is absorbed and cleansed,—such land having been carefully underdrained so as to secure aëration and thorough infiltration.

A description and the drawings showing this invention—which is now getting into use—are given in the Appendix.

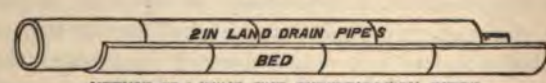
The regulator has been in operation at Eastwick, near Leatherhead, in Surrey, more than $3\frac{1}{2}$ years. There the liquid refuse of a mansion, a small hamlet, and a home farm (see Appendix, *Drawing* III.), is

brought by an underground conduit to the regulator, and thence is discharged on to a piece of land about ¾ of an acre in extent, situated about 300 yards from the mansion. The sewage is collected and discharged, independently of all personal attention, upon this land, the surface of which is ridged and furrowed. Down certain furrows the sewage is run one day, and down other furrows the next, and on the ridges excellent crops of cabbages and other vegetables are grown, fed by the sewage in the furrows, in which have been placed such "stops" as will retard the flow as required.

LVII.—Reasons why Sub-Irrigation may be Dangerous. Sub-irrigation has been suggested as another means of disposing of the sewage of dwellings. It has been received with favor, and has been adopted on free soils with apparent success, but as the liquid is distributed by underground pipes through the subsoil, and they are out of sight, the process is liable to objections, even if the subsoil is drained, which sanitarians cannot fail to recognize.

The foremost of these objections is the fact that the distributing pipes must sooner or later become choked with the minute solid matters held by the liquid refuse in suspension, and when this is the case an "excrement-sodden" condition of soil is produced. A stoppage can only be detected by positive signs of wetness on the surface, and not until the evils produced by exhalations from excrementitious matter may have gained an ascendancy. Mr. Rogers Field has done much to overcome these objections. The drains by which he effects the distribution of the liquid, and which consist of common two-inch agricultural drain pipes, are laid some 10 or 12 inches below the surface on a continuous bed formed of larger pipes divided longitudinally into two equal parts as shown in the following figure.

Fig. 1.



METHOD OF LAYING THE SUBIRRIGATION PIPES

This bed is not disturbed when the pipes are taken up to be cleaned, which ensures their being readily relaid in true position. The sewage flows out of the joints into the soil, and feeds the vegetation, and the concentration of the flow, effected by the sudden discharge of a flush tank with which the drains are connected, and which will be hereafter explained, forces the liquid rapidly along the pipes.

Sub-irrigation, however, is a process faulty in principle, as it feeds vegetation by the upward rising of moisture accompanied by

evaporation, with all the chilling influences which are so injurious to vegetation as well as to human beings.

When I proposed to the late Lord Palmerston, 15 years back—whilst engaged in the drainage of a portion of the Test Valley, situated near his seat at Broadlands—that his lordship should adopt sub-irrigation by admitting water from the river into the under-drains of some meadows at a lower level—an arrangement which could be readily effected by closing the outlets—he reminded me that every good gardener had abandoned the old practice of watering plants in pots from the saucers beneath them "because," he said, "they found that plants were not maintained in the same healthy vigour when there existed superabundant wetness at their feet, as when they were supplied with water in moderation from above."

LVIII.—External Sewerage of the Dwelling. The private communicating sewer to connect the dwelling with the (public) common sewer, or with the "cesspool or other like receptacle,"—such as the regulator just described—should conform to the following conditions.

(1) *Construction.* It should be constructed of stone-ware glazed pipes jointed in such a manner as to form a perfectly water-tight conduit resisting alike the influx of subsoil water into it, and the efflux of sewage out of it, and resisting also the intrusion of the roots of shrubs and trees which manage in the most extraordinary manner to find a passage into both drains and sewers through the joints. Puddled clay fails to secure a perfect joint near roots which run in search of water, and it also fails where the pipes are laid in a dry soil, where drought and evaporation will cause the clay to crack, and to destroy its water-tight condition. When cement is used too great care cannot be exercised to prevent cracking, as minute rootlets creep through the least fissures. Tarred gaskin and cement are the best materials for rendering joints water-tight and, at the same time, capable of resisting the intrusion of tree roots. The advantage of a water-tight sewer will commend itself to the occupiers of dwellings by the fact that if the sewage finds its way out of an imperfectly constructed sewer, the sedimentary particles will be left behind in the sewers to collect within and ultimately choke it.

(2) *Position or Course.* A sewer should in no case where it can possibly be avoided pass under the dwelling. Where, however, in crowded towns, this cannot be avoided, the private communicating sewer should, if possible, be laid under a passage or paved floor, and

it should be bedded in concrete and provided with a ready means of inspection without breaking the pipes (see Section LXXXIV.). Any sewer thus passing under the dwelling, should be carried completely through from outside to outside, having at each end a trap with grated covering, so as to gain thorough ventilation, *i.e.*, a passage of air along its entire length. On the upper side it should also be provided with a means of flushing in order to keep the pipes clear of deposit, and the pipes themselves should be carefully relieved from pressure by arches when passing under walls.

The course of the private communicating sewer from the dwelling to the common sewer or outfall should be as direct as possible, and where one line cannot be adopted, it should consist of straight lines from angle to angle, at each of which an inspection and ventilation shaft or covered sumpt should be provided. Care should be taken by the use of concrete or by other expedients to prevent the sinking of any of the pipes in infirm soils and to sustain true lines of continuity. A faulty sewer close to a dwelling is always to be dreaded from the circumstance that the inner warmth of the dwelling will draw in any noxious gas existing in the sewer through the fault itself. The union of the private communicating sewers with the common or outfall sewer should be effected by a curved junction (see *Figs.* 2 and 3), so that the sewage should be delivered to the

Fig. 2.

Fig. 3.

common sewer in the direction of the main current, and where possible at a sufficient height above the level of the ordinary flow of sewage to prevent the sewage being "backed" or forced into them from the common sewer.

(3) *Inclination and Velocity.* The private communicating sewer should be laid with an inclination which will secure for its contents a velocity of not less than three feet, and not more than 10 feet per second wherever those limits can be regarded. Where

a less velocity than three feet per second can only be obtained, more than ordinary care must be exercised to secure the best formed and best glazed pipes, in order to prevent the adhesion of solid matter to the sides of the pipes. Where it is not possible to procure the desired velocity for the ordinary flow of the sewage to be discharged, an effective and special means of flushing must be provided, which should be automatic in its action if possible.

(4) *Size.* No private communicating sewer need exceed six inches in diameter, except in very large establishments or institutions containing a large number of inmates, when nine-inch pipes, or pipes of an intermediate size, may better answer the purpose.

The following table, giving the velocity and discharge of different sized sewers laid with different inclinations and running full, will be suggestively useful:—

Diameter of pipe.	180 ft. per minute, 3 ft. per second.		270 ft. per minute, 4½ ft. per second.		360 ft. per minute, 6 ft. per second.		540 ft. per minute, 9 ft. per second.	
Inches.	Fall.	Gallons per minute.	Fall.	Gallons per minute.	Fall.	Gallons per minute.	Fall.	Gallons per minute.
3	1 in 69	54	1 in 30·4	81·0	1 in 17·2	108	1 in 7·6	162
4	1 in 92	96	1 in 40·8	144·0	1 in 23·0	192	1 in 10·2	288
6	1 in 138	216	1 in 61·2	324·0	1 in 34·5	432	1 in 15·3	648
9	1 in 207	495	1 in 92·0	742.5	1 in 51·7	990	1 in 23·0	1485

The above table will help to fix the size of pipes used for dwellings, the Engineer making such deduction or allowance as the special conditions of each case may demand. In applying the table practically, reference should, of course, be had to the maximum rate of outflow which may take place at any time of the day. It will be observed that the number of gallons which the different pipes are capable of discharging in a minute, when running full at the different inclinations specified, will often exceed the total quantity of sewage to be discharged from a dwelling in the whole of the day, and yet it may be desirable to use a pipe with such excessive capabilities of discharge.

(5) *Liquid Refuse from Water-Closets and Urinals.* It is desirable, if it can be effected without nuisance, to disconnect the soil-pipe of water-closets from the sewer by a trap arrangement effecting a break in its continuity outside the dwelling; but there is so much probability of an evil arising, sooner or later, from the use

of such disconnecting traps, which would in itself be as great as that which it is intended to remove, that I consider it better not to break the continuity of the soil-pipe of water-closets, but to trust to well-devised double trapping, with proper ventilation of the soil-pipe and closet trap, (see *Fig.* 2, *Drawing* I.) to prevent the escape of sewer gas into the dwelling and the water in the pan from becoming fœtid, and to prevent, too, one trap unsealing another trap by the power of suction which sometimes takes effect when the plug of a higher or lower closet discharging into the same soil-pipe is used.

(6) *Liquid Refuse from Sinks.* The sundry outlet pipes from the scullery sink and other sinks of the dwelling (see *Figure* 2, *Drawing* I.), which should themselves be trapped inside the dwelling, should, under no circumstances whatever, be connected directly with the communicating sewer, but should discharge upon the grated covering of a trap or gully fixed immediately outside the wall of the dwelling. Thence the liquid passes into the trap, and by the trap into the sewer. The trap being itself ventilated, as well as the sewer, by a special shaft or pipe taken up the house wall, any effluvia generated in or rising up from either, will escape into the air and not into the dwelling.

The trapping of the outlet pipes at or under the sinks is necessary to prevent the effluvia from the trap being drawn into the dwelling by the greater warmth of the inside air. All solid matter discharged by the sink pipes, which will not pass through the grated covering, should be treated as belonging to the scavenger, and be removed to the ash-pit.

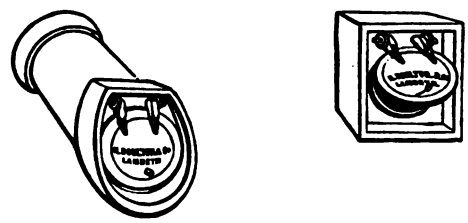
(7) *Inspection Shafts.* Where the private communicating sewer is of considerable length, and follows a course favourable for the provision of inspection shafts, such as may be formed of pipes rising the surface, they will be found useful for observing the flow of sewage, and for ventilating the sewer itself. Care is necessary in placing these shafts so as to avoid the objection of an escape of gases in frequented places.

(8) *Removal of Grease and Solid Matters deposited in Trap-Tanks or Gullies.* To keep the private communicating sewer clear of the deposit of kitchen grease (the worst of all impediments) and

other clogging substances, a means of readily intercepting and collecting these matters in a trap-tank should be insisted upon. Field's flush-tank does this. When the liquid sink refuse, relieved of these solid portions, can be automatically discharged in sufficient quantity, it should be used for flushing the sewer, and the collected grease carefully removed from the trap-tank (see *Fig.* 30).

(9) *Gases from common Sewers.* To prevent the gases generated in the common sewer from passing up the private communicating sewers, light flaps (see *Fig.* 4) may sometimes be advantageously introduced at the junction of the one with the other. This

Fig. 4.



arrangement can only be effected when the common sewer is constructed in brickwork, and where an increased fall can be given to the private sewer just above the junction. I am using very light flaps hung on balance hinges, made by Flood and Co.

Syphon traps may also be occasionally introduced for the same purpose. As a rule, however, both flaps and traps are to be avoided if possible, and when used the evils by which they are sometimes attended should be specially guarded against by the best of workmanship and arrangement.

LIX.—THE VENTILATING AND FLUSHING OF THE EXTERNAL SEWERS OF THE DWELLING. Two important objects in connection with the private communicating sewers of dwellings are essential to

*** The woodcuts used to illustrate these Lectures, have been kindly furnished me by the makers of the apparatus figured.

a perfect system. I refer to ventilation, for the purpose of freeing the sewers of noxious gases and effluvia, and to flushing for securing the frequent clearance of deposit.

Ventilation may be effected, as already stated and as shown in *Drawing* I., by pipes—(1) in continuation of the soil pipe of the water closet, and (2) in connection with the communicating sewer at the trap-tanks or gullies into which the several sinks of the dwelling discharge.

Ventilating pipes should not be less than three inches in diameter —better if four inches,—and should be carried up above the roof of the dwelling to avoid the possibility of the passage of gases or effluvia by the windows into the dwelling. (See *Drawing* I.) As a rule the down pipes for the discharge of rain water from roofs should be avoided as ventilators, though probably in certain cases they may be used without objection. Perfect circulation of air through the communicating sewer of the dwelling may be secured by the double ventilation to be effected by an inlet at the ground level and an outlet at the roof. This simple arrangement is a very important one. It will doubtless occur to you that if every private dwelling in a town or village were possessed of such a mode of ventilation, the effluvia which now often rise up into the street from manholes, lampholes, and gullies, and thence through doors and windows into houses, would be avoided. It has been proposed, in order to secure a constant "up"-draught to the ventilating pipes attached to dwellings, that a hood or cowl, revolving with the wind, should be placed on the top of them, which by its special construction shall draw out the contents of the pipe and "induce an upward current" from below. There are several inventions aiming at this object which will be described when speaking of the ventilation of the dwelling, but all such arrangements are only to be recommended when a proper circulation of air cannot be secured by natural ventilation. (See *Drawing* IV.)

The second object, the flushing of the communicating sewer, may be generally effected in two ways; first, by a sufficiently copious and well regulated supply of water to the water-closets inside the dwelling each time they are used, and next, by a sufficiently frequent and automatic discharge of the liquid refuse of the sinks after it has been collected in the trap-tanks outside the dwelling. The supply of the proper quantity of water to the closet is secured by special arrangements connected with the closet itself, whereby a precise quantity—say of two gallons—must pass through the basin and

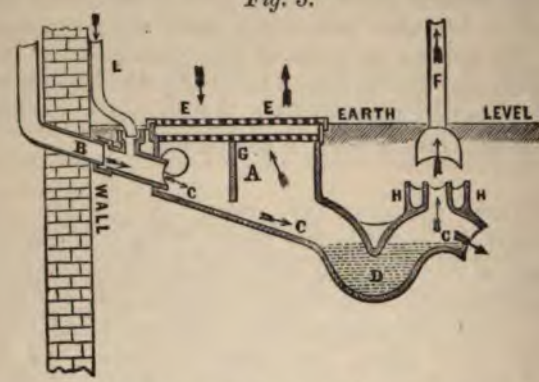
soil pipe on each occasion of use, while the collection and automatic discharge of the sink liquid may be effected by Field's flush tank, (which will be hereafter particularly described) or some such contrivance. By the use of tanks of this character the rain water from the roofs may also be turned to account for flushing, and, as it is only when the tank becomes full that its contents are discharged, the slightest showers are made to contribute.

LX.—Water Closets and their Appliances, and the Arrangements for Ventilating them. With very few exceptions the excremental refuse of superior dwellings throughout this country is discharged through the medium of water-closets, the only exceptions being those comparatively few instances where earth closets have taken their place, and those instances where neither earth nor water-closets exist *within* the dwelling, the inmates still following the old but waning practice of using external closets of some kind or other. Two important objects should be aimed at wherever water-closets are used in the dwelling: (1) they should be so placed that no objectionable smell shall find its way into the interior of the dwelling when they are used; (2) their machinery should be so arranged that no gases from either sewer, soil pipe, or trap, should escape inwards. To effect the first object all water-closets should be constructed against external walls with a means of direct open-air ventilation, and there should be in addition, wherever it can be so arranged, a lobby, ante-room, or passage, provided with a like means of ventilation, between the closet and the interior of the dwelling, and a second door should cut this lobby or apartment off from the interior of the dwelling. To prevent the escape of gases from the soil pipe into the dwelling, a double trap with a double means of ventilation should be provided between the closet basin and the soil pipe. The double trapping is effected first by a syphon, or other trap, in connection with the soil pipe, and next, by a valve or pan fitting the bottom of the closet basin, while the double ventilation is effected first, by a continuation of the soil pipe upwards to the roof; and next, by a branch into it from the trap beneath the closet basin as shown on *Drawing* I., *Fig.* 2. Very much depends on complete ventilation.

When laying down rules for the external sewerage of the dwelling, I stated that it would be desirable to break the continuity of the pipe from the water-closet to the sewer, if it could be effected without nuisance. The trap known as the "Patent Edinburgh Air

Chambered Sewer Trap" (shown in *Fig.* 5.) has been invented for

Fig. 5.



this purpose, and weighty evidence has been given in favour both of its utility and freedom from objection. It is manufactured by Messrs. Potts and Co., of Handsworth, near Birmingham, and is thus described by the inventor :—

A is an air-chamber 2ft. 6in. or 3ft. long. **B** is the soil pipe from closet. **C C C** shows the course of soil through trap to sewer. **D** is an ordinary water valve or syphon. **E E** is an open grating raised two or three inches above the ground level, having a second grating or tray below it, on which charcoal or other disinfectants may be placed. **F** is a pipe reaching to the roof, about two inches diameter; this pipe is so fitted to the trap that it can, if desired, be luted with sand or plaster, so as to admit of its being readily raised to give access to the pipes for clearing purposes. **H H** is the lower portion of joint for pipe **F**, showing opening to trap. **G** is a division plate or diaphragm, dividing the air-chamber into two parts; it assists in directing the gas out of the chamber **A**, and acts so as to create a current of air through the trap. **L** is a pipe joining the soil pipe by a junction before it enters the air-chamber.

The trap should, where practicable, be placed parallel to the wall of the house, and the soil pipe should be so arranged as to enter into the air-chamber as shown in the wood-cut; this can be effected by turning the end of the soil pipe, even when the sewer follows a course at right angles to the wall of the house. It does not interfere with the action of the trap if the soil pipe enters the air-chamber at the side, but it is not so good for flushing purposes.

Housemaid's-sink or waste-water pipes may enter at the side, and where more than one closet is connected with the trap, the connection may be made at the sides. The pipes so connected should be obliquely inclined towards the bottom of the trap and sewer. It is imperatively necessary that the grating E E should stand a little above the ground level and be open to the air; it matters not how much, provided it be not less than two or three inches, so as to prevent the admission of gravel or sand with surface waters. In

cases where it has to be fixed to pipes much below the ground line, it is necessary to build up the sides of the air-chamber until they reach the surface or an inch or two above it. This is readily done by slabs of slate, stone, or brick (the former are best) on which the grids may be placed. It is absolutely necessary to leave the top of the air-chamber open to the air, whatever may be the depth at which it is fixed.

I have thought it right to describe this invention somewhat fully, because, although I am unable to recommend the arrangement, there can be no doubt of its value if the object at which it aims can be perfectly fulfilled.

With respect to the precise character of water-closet to be recommended, much care in selection is needed, for a great number of those now in use are of a very imperfect nature. Many descriptions of closets have a great tendency to collect within them a portion of the foul matter it is their purpose to discharge, and thus to partake of the nature of small cesspools. The closets provided with what is known as the "D" trap are especially objectionable on this account, as are also the "pan" closets, which should always be looked upon with suspicion.

Where it is desired to have an outside water-closet, or where the apartment in which the apparatus is fixed is well separated from the remainder of the dwelling, and there is a good command of water, much may be said in favour of the Hopper Closet (see *Fig.* 7.) as

Fig. 7.

Fig. 6.

Fig. 8.

made in stoneware by Doulton, and others. It consists of a basin and a single trap only, the simplicity of which affords little chance of its getting out of order. There is an entire absence of valves of any kind.

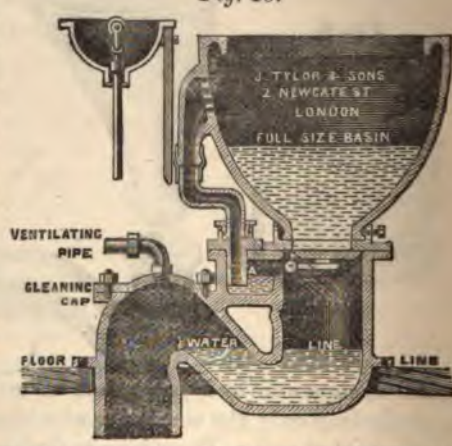
In small dwellings with plenty of water this closet answers its purpose admirably, and where waste of water is feared from its use it may be prevented by the addition of one of the simplest "Waste-not" contrivances, which limit the supply of water to an intended quantity.

For the larger class of dwellings in which a more perfect freedom from an escape of effluvia is aimed at, the superior closets of Tylor and Son, of Newgate Street; Underhay, of Farringdon Street, London; Jennings, of Lambeth; and some others are to be preferred.

Figs. 9 and 10 show one of Tylor's water-closets called "The Patent Valve Closet."

Fig. 9.

Fig. 10.

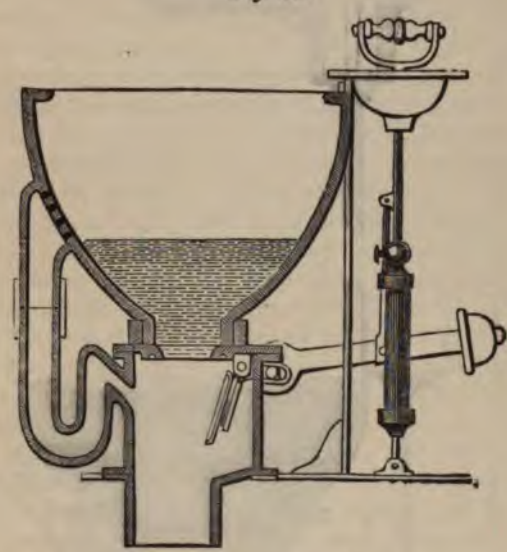


This closet is trapped in two places above the floor line without any reduction in the size of the basin—a point in which many closets are deficient—or any increase in the height of the seat. The syphon forming the lower trap may be readily opened for inspection by means of the "cleaning cap." The overflow pipe from the basin is also trapped, (see A, *Fig.* 10), and the entry of the contents of the basin into this trap is prevented by its being covered by the discharge valve of the basin, when open. It will be observed that the outer elbow of the soil pipe is ventilated by means of a pipe, an arrangement which might be improved by the ventilation of the space between the water line in the syphon and the

bottom of the closet basin. Tylor's "Waste-not" regulator is attached to the supply pipe (see *Fig.* 9), and is acted upon by the handle of the closet. The "waste-not" is more particularly explained hereafter, and is shown by *Fig.* 16.

One of the excellent water-closets of Underhay, of Farringdon Road, London, is shown by *Fig.* 11.

Fig. 11.

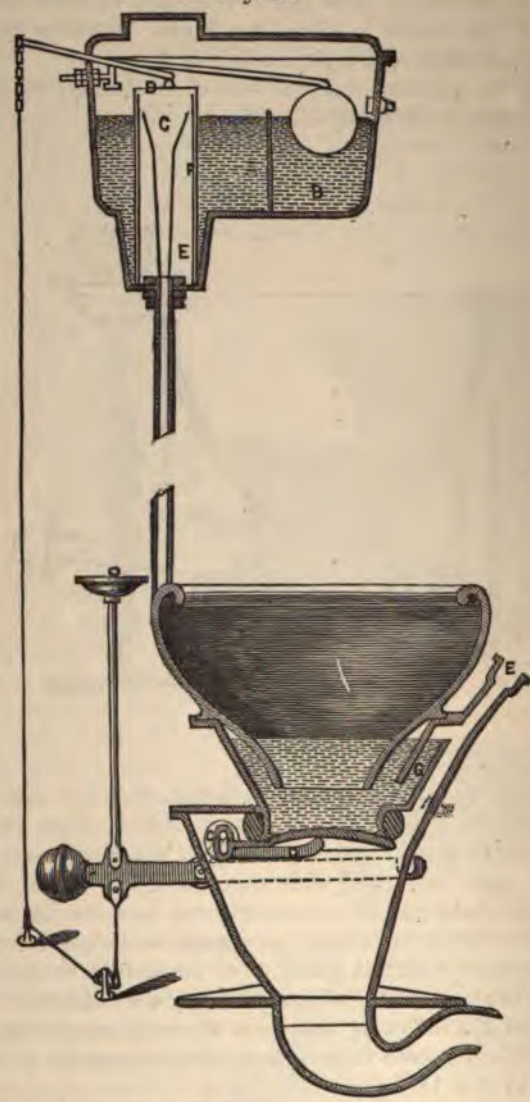


The trapping of the basin is effected, as in the case of several closets made by Tylor & Son, by the provision of an India-rubber seating, which shuts against the valve, while the over-flow pipe from the basin is formed into a syphon. A want of ventilation beneath the closet pan is here experienced, and should be supplied. Underhay's Patent Regulator—an apparatus designed for insuring the discharge of a certain quantity of water into the pan, independently of the user of the closet, who may drop the handle and still not prevent the inflow of water.—is shown in connection with this closet. This regulator is more particularly explained hereafter, and is shown by *Fig.* 18.

Fig. 12 shows a closet manufactured by Messrs. Peters and Donald, of Glasgow in which the ventilation of the space between the two traps—to which I have referred in connection with both

the two foregoing closets—is provided. This ventilation, it will be

Fig. 12.



seen, is effected by a pipe called the nozzle tube E, which is connected with the overflow pipe (G) from the basin. The valve arrangement

of this closet is composed of a brass disc which is closed against an india-rubber ring by means of a projecting arm cast on the spindle C. This spindle is passed through an oblong hole in the tail of the disc so that the latter is not fixed but hinged on the spindle. By this arrangement, the patentees state, the disc is closed perfectly tight against any slightly uneven surface which at times may present itself. This closet is shown in connection with the "Valveless Waste Preventer," of Messrs. Peters and Donald, who describe the working parts of this contrivance as consisting of a stationary copper tube F, standing in the cistern above the water level. In the centre of this is a copper tapered tube C connected to the down pipe. Over the stationary tube F is suspended a copper tube of larger diameter, but of the same length, having a closed end D, which is attached to the cistern lever. A small air hole is pierced near the top of tube D, which allows the water to stand in the space between the tubes D and F at the same level as that attained in the cistern. When the cistern lever is pulled down, the larger copper tube D is drawn up over the inner tube F. This action forms a partial vacuum in the down pipe or tapered tube C, and space E; the water rushing in to fill up the vacuum thus formed starts the syphon, the longer arm of which consists of the down pipe and tapered tube C, the shorter arm being the space between the inner tube F and outer cap D. When once the syphon is set in action, it will continue running until the whole contents of the cistern have been discharged, provided the cap D be held up, but the action will stop immediately the cap is allowed to fall. The water that has passed into the space E between the tubes C and F while the syphon was in action, is allowed to pass through a small hole in the tapered tube C into the down pipe. This water serves to seal the closet after the handle has been put down. The size of the compartment in which these tubes are placed, limits the quantity of water that can be used each time the closet handle is pulled. It is filled from chamber B by means of a small hole in the division plate.

The valve closet of Jennings, of Lambeth, has much to recommend it for its simplicity of construction and compactness, the closet and syphon trap being made of one piece of earthenware. This closet is shown, though somewhat imperfectly, by *Fig.* 13. Mr. Jennings is now fitting this closet with a regulating supply valve, whereby the supply to the basin may be increased or lessened at will. The socket or branch marked P in the figure is provided for the reception of a ventilating pipe. It is not,

however, quite in the right place, and should be altered as suggested in *Fig.* 9.

Fig. 13.

Jennings' closet requires further improvement at the hands of its clever inventor in order to make it complete. It should be provided with a trapped overflow from the pan instead of using the hollow plug for the purpose, which will allow effluvia generated in the trap to pass through the plug into the closet.

I am guilty of no exaggeration when I say that there must have been at least a hundred kinds of water-closets which have been patented. An examination of their several characteristics, in addition to those of the closets I have specially figured, will repay those who are interested in the very important subject of internal water-closet arrangements. In addition to the closets of the makers whose names have been already mentioned, I would particularize those of Messrs. J. G. Stidder and Co., of Southwark; Messrs. Bolding and Sons, of South Moulton St.; Mr. James Woodward, of Swadlincote; and Messrs. Forrest and Son, of Liverpool; as deserving of special attention.

Many are the supplemental appliances, too, that have been devised to make water-closets more perfect in their use,—some securing the flushing of the basin by the use of a certain quantity of water each time the closet handle is pulled up, while others are designed not only to gain this desideratum but to prevent the use of more than a predetermined quantity of water for the purpose—an object of some importance where the supply is constant, and where, therefore, liability to waste and abuse must be avoided.

In adopting any of these appliances, however, care should be

exercised that none but those based upon sound constructive principles, and possessing the greatest freedom from wear and tear are adopted, as otherwise their use will lead to much derangement and annoyance. The great object to be secured in the delivery of water to the closet is that it shall completely wash and flush out the basin and traps. To do this it should be borne in mind that the result will depend—not upon the length of time the water is allowed to run through the closet—but upon the force and volume with which it is discharged.

Figs. 14 and 15 show the "Waste-not" cistern valve of Messrs. Tylor.

Fig. 14.

Fig. 15.

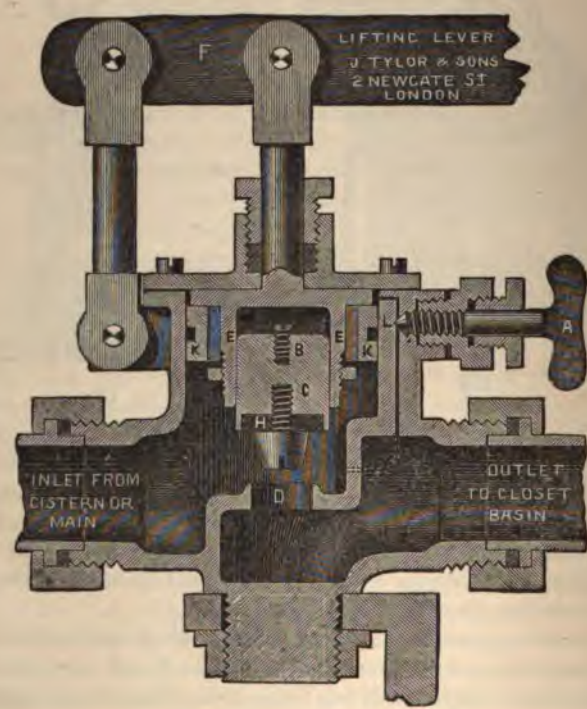
This valve is fixed in the cistern supplying the water to the closet; and the advantage of its use consists of the fact that it will automatically close, after allowing the intended quantity of water to pass, in whatever position the closet handle which opens it may be left, thus preventing the running of an excessive quantity down the closet. An air-pipe, as in ordinary closet valves, should be fixed to the down pipe and carried up outside the cistern.

The piston regulating valve C is fitted with a washer valve, and moves loosely up and down in a fixed cylinder F. E is an adjustable socket or piston. When the ball lever of the closet apparatus, which is attached to the spindle A, is pulled up it raises the adjustable socket or piston E, which takes up with it the piston regulating valve C, and opens the passage for the water through the valve.

When the spindle A is dropped the piston E descends immediately and with it the valve C on to the seating D, and the passage of water is closed. When the ball lever attached to spindle A is held or propped up the valve C descends gradually on to the seating D, and closes of itself with the stream, allowing only the intended quantity of water to pass, usually regulated to two gallons, though a less quantity can be run by screwing down the nut K.

Fig. 16 exhibits on a large scale the "waste not" referred to in connection with *Fig.* 9, its position when fixed being beneath the closet seat as there shown. It is constructed on

Fig. 16.



principles exactly similar to the "waste not" cistern valve just

described. C is a plunger fitted with a washer valve H at the bottom, and moving up and down in a metal or elastic socket E E, which forms a carrier, and which is fixed to the spindle connected with the lifting lever F. This valve is made, if preferred, with a flat elastic washer or diaphragm (instead of E E). K K is a ring valve for the purpose of controlling the descent of the metal or elastic socket E E. L is a passage way by which the water flows from under to above the ring valve K K, and is partially opened or shut by turning the tap A. When the handle of the closet is pulled up the lever F raises the metal or elastic socket, E E, which lifts by suction the ring valve K K, and the plunger C, and thus opens the passage for water through the valve. When the closet handle is dropped, the lever F commences to fall, the speed of its descent being regulated by the quantity of water which is allowed to pass through the passage way L. If the closet lever F is held up, the metal or elastic socket, E E, and ring valve K K, will be kept up too, but the plunger C will be taken down on to its seat D, partly by its gravity, but principally by the pressure of the water. The adhesion or attraction should cease, and the plunger C should begin to fall, when the pressure is made equal inside and outside the socket.

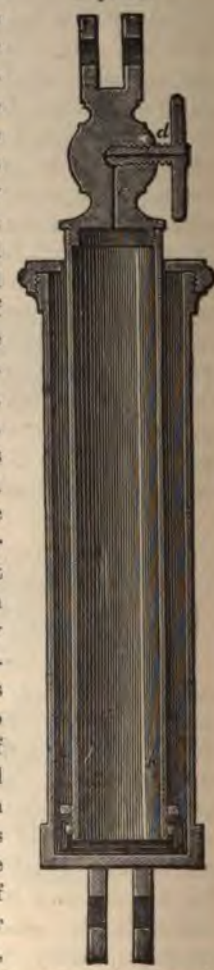
I have been induced, by the clearness of the drawing (*Fig.* 16) to give a detailed description of this contrivance.

Messrs. Tylor manufacture another "Waste-not" valve, for use outside the cistern. This valve is similar in principle to the foregoing, but is made in the form of a tap which takes the place of the closet handle as shown in *Fig.* 17. The tap can be turned, and if the water be left running it will close automatically after the intended quantity has passed, which is usually about two gallons. In certain cases, where a "hopper" closet is used for instance, this arrangement may be recommended.

Fig. 17.

The patent Regulator of Underhay, referred to in connection with *Fig.* 11, is shown upon an enlarged scale by *Fig.* 18. (See also *Fig.* 20.)

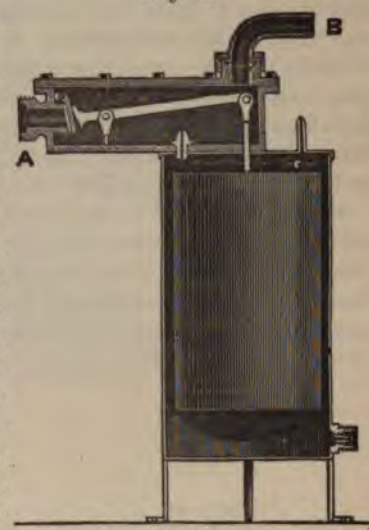
Fig. 18.



The object of this invention is to allow the passage of a certain quantity of water through the pan of the closet each time the handle is raised. For this purpose a vessel—by preference a cylindrical vessel—is adopted, which is closed at the bottom and provided with an air inlet near the top. Within this is a second cylinder, which is open at the top to a small extent only, but entirely open at the bottom. The inner vessel is of such dimensions as will allow of its working up and down readily within the outer one. Around and near the lower part of the inner vessel is a cup of leather, or other suitable flexible ma terial, the lower edge of which descends into some lubricating fluid at the bottom of the outer vessel, each time the inner vessel is caused to descend. By this means the interior of the outer vessel is lubricated each time the inner vessel is raised. At the upper part of the inner vessel an air-cock *c* with a regulating screw *d* is provided, the latter being adjusted according to the time which it may be desired the inner vessel should take in descending. The outer vessel is fixed in any convenient position, and the inner vessel is connected to the closet handle. When the latter is raised the inner vessel above mentioned is also raised, which can readily be done by reason of the cupped leather or other flexible material giving way and acting as a valve. A certain quantity of air will be admitted by this process to the bottom of the inner cylinder. When the closet handle is left to fall back, the pressure of the air will keep the outer edge of the leather against the interior surface of the outer vessel, and the inner cylinder will only descend as the air escapes by the air valve mentioned. In this way the lever of the closet is kept open for the discharge of water until the inner cylinder has descended to the bottom. This occurs each time the closet handle is raised.

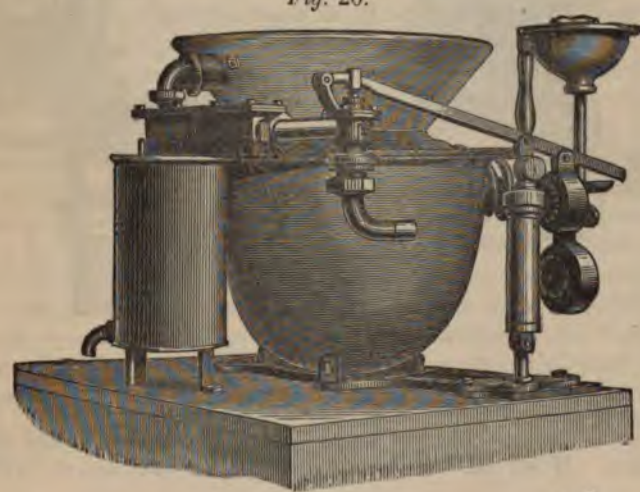
Fig. 19 shows another contrivance of Underhay, which he calls the "Water Waste Preventer." This instrument is affixed to the supply pipe of the closet, and in principle is somewhat similar to the regulator. Like that contrivance it consists of one cylinder within another, and as the water runs from the cistern or supply pipe to the pan of the closet (from A to B) a certain regulated proportion escapes through the small aperture shown on the figure into the space between the outer and inner cylinders. Within a determined period this influx of water floats and gradually raises the inner cylinder, which, being connected with a lever for the purpose, closes a valve in the water supply pipe A, and prevents the entry of any further water until the preventer has had time to empty itself of its contents by the small outlet at the bottom.

Fig. 19.



The relative positions of both the "Regulator" and "Water Preventer" are shown by *Fig.* 20. By the combined use of these

Fig. 20.



appliances it will be found (1) that the closet handle cannot replace itself and close the supply valve until the pan has been well flushed, and (2) that no more than a certain quantity of water can be used at one time. This arrangement is only shown in the figure (20) in order that the respective positions of these appliances when fixed may be understood. It is not intended to convey any approval of the character of the closet with which they are shown to be connected, the under-basin of which may be fairly objected to as being subject to the accumulation of filth without any ready means of cleansing it.

Figs. 21, 22, and 23 show the "Sure Water Waste Preventer and Self-sealing Closet Supply Valve" of Messrs. Wallace and Connell, of Glasgow—contrivances which secure to the closet a certain quantity of water each time the handle is pulled up, and a second quantity to trap the closet pan after the handle is put down.

Fig. 21.

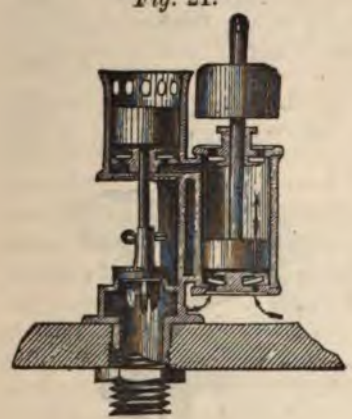


Fig. 22.

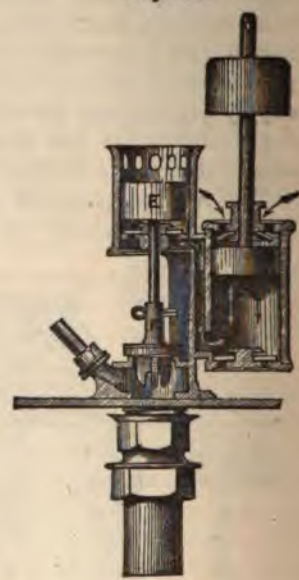
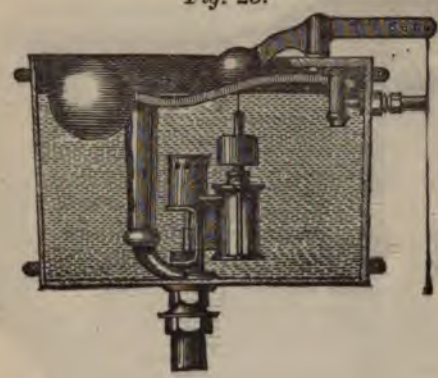


Fig. 21 shows the contrivance when the closet handle is at rest; *Fig.* 22 shows it when raised, and *Fig.* 23 its position in the water cistern. When the closet handle is raised the lateral cylinder

of the valve is also raised and the water above it is drawn in and forced up to the main cylinder in the direction of the arrows

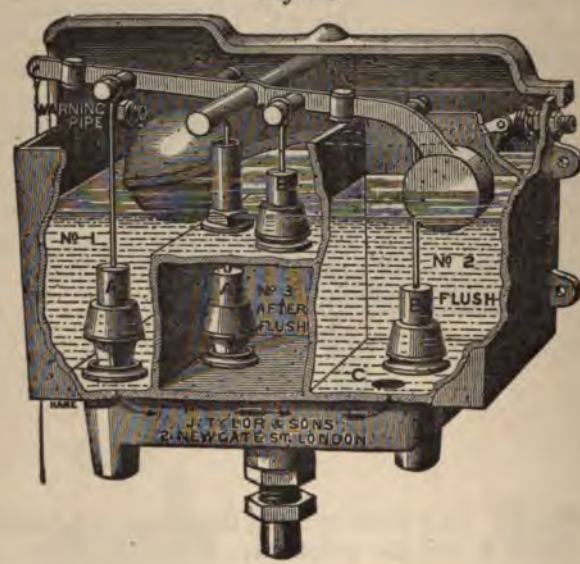
Fig. 23.



shown on *Fig.* 22. This water, entering the main cylinder suddenly, raises the piston E and the outlet valve to the closet (F). The piston E fits loosely, and is so weighted that while it will rise with the sudden rushing of the water up to it, it will afterwards gradually sink and force the water out past its circumference, and with its fall it will close the inlet valve to the closet. The time taken for the descent of the piston E will determine the quantity of water which can pass each time the closet handle is raised. When the closet handle is released the piston in the lateral cylinder will fall and the water under it will be forcibly and suddenly pressed into the main cylinder, again raising the piston E, and the valve F, and thus the outlet to the closet is opened a second time, the piston afterwards slowly descending as before, and this second discharge forms the trapping supply of the closet. This contrivance has therefore two distinct actions each time the closet is used—the first flushes the closet and the second gives the trapping water to the pan, and however long the handle may be held up, this latter water is reserved until it is released. The holes at the top of the main cylinder limit the use of the piston by allowing of the escape of any excess of water forced under it.

The "'After-flush' Waste-Preventing Closet-Cistern" of Messrs. Tylor is shown by *Fig.* 24.

Fig. 24.

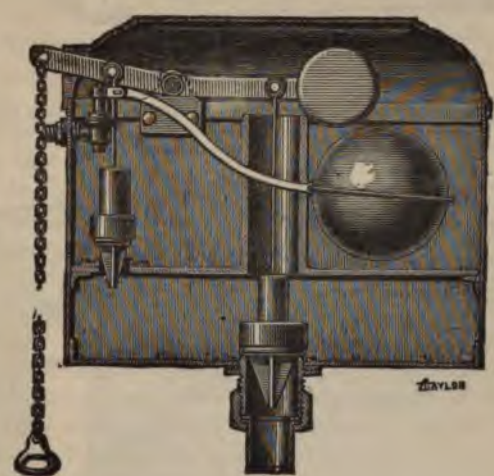


This apparatus consists of a cast-iron cistern about 20 inches long, 11 inches wide, and 10 inches deep, having three compartments. In these compartments there are two pairs of valves, AA and BB. When AA are open BB are shut, and *vice versa*. *Fig.* 24 shows the apparatus at rest. The valves AA are then open and BB are shut. Directly the closet handle has been released after the closet has been used, the water will have passed through the ball valve into compartment No. 1, and from thence into compartment No. 2, through the aperture C by the passage shown by the direction of the arrows, filling both compartments, the "after-flush," compartment, No. 3, remaining empty. When the handle of the closet has pulled down the lever and opened the valves BB, the water rushes out of compartment No. 2, and flushes the closet, and at the same time No. 3 "after-flush" compartment is filled from No. 1. When the handle of the closet is let down, the lever of the cistern falls with it, the valves AA are again opened, and the water from the "after-flush"

compartment No. 3 is discharged into the closet basin, which it seals; the water from No. 1 running into No. 2, as already described. By this arrangement the trapping of the closet pan is secured, as the water intended for that purpose is not discharged until the valve of the closet pan has been closed.

Fig. 25 shows the ingenious "Improved Double Chambered Water Waste Preventer Cistern" of Messrs. Stone & Co., which has been devised, like several of the inventions we are now considering, to prevent the use of more than a certain quantity of water each time the closet handle is pulled.

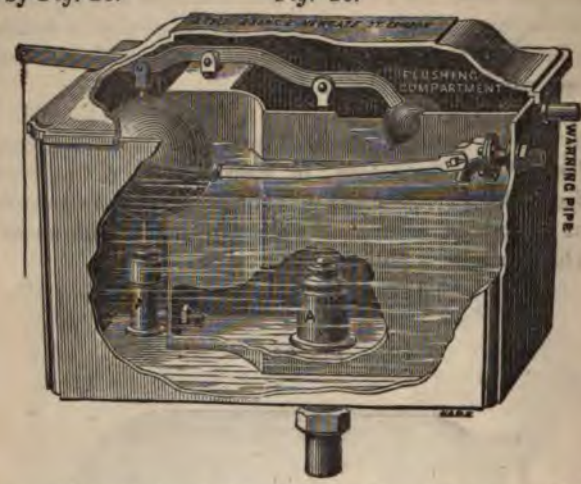
Fig. 25.



In this cistern there are two chambers—an upper and a lower one. The upper chamber is filled by means of a ball valve and emptied through a discharge valve into the lower chamber, which is constructed to hold 2 gallons. In the lower chamber there is also a discharge valve, and the apparatus is so arranged that the valve leading into the lower chamber, and that leading out of it, cannot be open at the same time. Thus, when the closet handle is pulled the top valve is closed and the bottom one is opened.

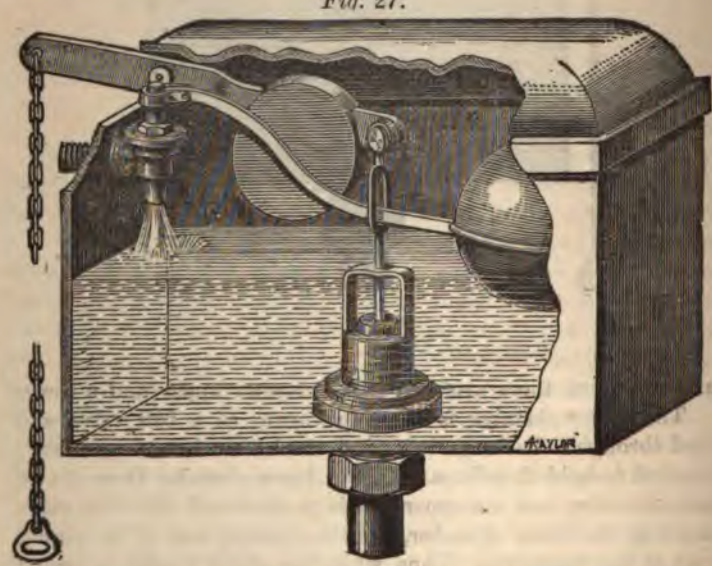
A somewhat similar cistern, made by Messrs. Tylor and Son, is shown by *Fig.* 26.

Fig. 26.



The same duty is aimed at by Messrs. Stone's "Single Chambered Water Waste Preventer Cistern," shown below.

Fig. 27.



The contrivance is so arranged that when the water is required

to be drawn off from the cistern the inlet valve must be closed before the discharge valve can be opened.

The cisterns shown by the three preceding figures are more applicable to Hopper closets than to valve closets, owing to the want of any provision to secure the delivery of the requisite quantity of water for trapping the basin, irrespective of the user of the closet, when the closet handle is released. This should be supplied.

The "Water Waste Preventer," manufactured by the well-known firm of Guest and Chrimes, of Rotherham, with whom Messrs. Beggs, of Southwark, are connected, is shown in *Fig.* 28. It has two chambers, the smaller one containing the inlet valve and ball connected with the supply pipe, and the larger one containing the water required for flushing the closet. The chambers are fitted with valves, which are connected with a lever at the top of the cistern, and which are so adjusted that before the bottom valve can be moved from its seat the valve in the ball-cock chamber must be completely closed. This preventer is applicable to hopper closets.

Fig. 28.

For valve closets Messrs Guest and Chrimes manufacture the "Waste Preventer" shown by *Fig.* 29.

Fig. 29.

This contrivance is constructed on the same principle as that just described (*Fig.* 28), but with the addition of a trapping box which, after the water for flushing the closet has passed, allows a sufficient quantity of water to flow down into the basin and fill it to the necessary height.

Messrs. Guest and Chrimes have also contrived a "Single Valve Waste Preventer," which has been adopted to a considerable extent.

The "Absolute Water Waste Preventer" of Mr. Chandler, Mile End Road, London, with his patent "Trapping Box," form together a very ingenious arrangement.

The cistern forming this waste preventer is without any of the divisional chambers shown in some of the foregoing contrivances. Its speciality consists in the provision of a double inlet valve, one being worked by a float which will rise and fall with the water, and the other by the handle of the closet. The latter valve—that worked from the closet—is placed nearest to the supply cistern, and when the handle of the closet is pulled up, the influx of water to the waste preventer is stopped. This valve is connected with the outlet valve which gives the water supply to the closet. When the closet handle is pulled up the inlet valve is closed and the outlet opened. As the water passes to the closet the float valve will

open gradually as the water sinks, and admit fresh water to the waste preventer directly the other valve is released by the closet handle and the outlet valve is closed.

One of Chandler's Patent Trapping Box is attached to the bottom of the cistern; and after the closet handle has been released, this box will be filled with water, which will empty itself into the closet to form a seal to the pan by means of a small hole.

Fig. 29a shows the "Trapping Box" of Messrs. Tylor and Sons, connected with the closet cistern and the closet itself.

Fig. 29a.

The trapping box is 6 inches in diameter and 6 inches deep, and contains sufficient water to trap the closet basin. The water to fill the trapping box is admitted (and collected in it) as that required to flush the closet basin passes down the pipe. This portion is accumulated as in Chandler's contrivance, to pass through a small hole into the closet pan after the handle of the closet is dropped.

In thus referring to these several contrivances, I do not wish to be understood to express an unqualified approval of them. I have shown and described them for the purpose of conveying an idea of the principles upon which the water-closet fittings now in most general use are constructed.

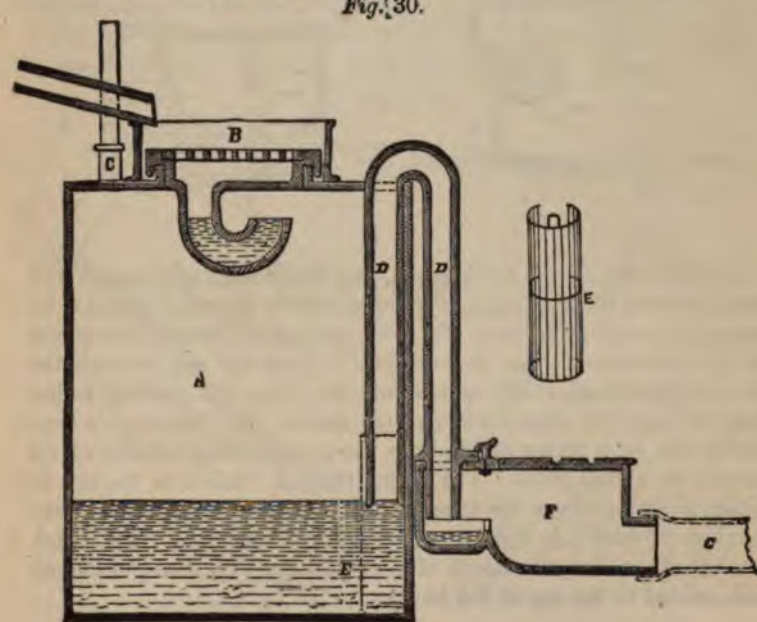
LXI.—Sink Appliances, and the Arrangements for Disconnecting the Outlet Pipes of Sinks from the Communicating Sewer.—Having already emphatically stated that the pipes discharging liquid refuse from the dwelling, (generally called "slops"), which is composed of the discharge from the sinks of the scullery, the butler's pantry, housemaid's, and other rooms, as well as the water from lavatories, baths, &c. (see *Fig.* 2, *Drawing* I.), should not be directly connected with the sewers, there is little more to say than to describe what has been done in this way.

In smaller houses one outlet from the sink, &c., will probably suffice, while in larger establishments there will be several. In each case, the liquid as it is discharged should fall upon a grating outside the dwelling, in order that those coarser solid substances which are often thrown down sinks, and which, if admitted into the sewer, would help to choke it, may, as already stated, be intercepted and removed.

Several trap-tanks with grated covers have been designed for the purpose of receiving the slops, and of preventing the influx of effluvia from the sewer into the dwelling.

Fig. 30 shows the "Flush-tank" of Mr. Rogers Field, to which reference has already been made.

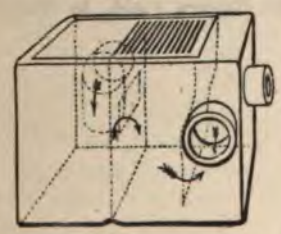
Fig. 30.



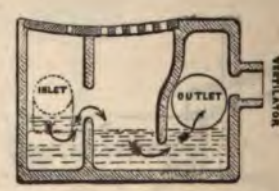
The apparatus consists of a cylindrical water-tight iron or stoneware tank A. This tank has a trapped inlet B (which also forms a moveable cover to give access to the interior of the tank), and a socket C for a ventilating pipe. The outlet consists of a syphon D, so arranged that no discharge takes place till the tank is completely filled with liquid, when the syphon is brought into action and the contents are immediately discharged. The inner end of the syphon is protected by a strainer E, to hold back grease &c., and the outer end enters a discharging trough F, which is made to turn round so that its mouth may be directed as required to connect the tank with the line of outlet pipes (G). This trough has a cover which can be removed to give access for cleaning. In this contrivance the liquid refuse from the house sinks is discharged on to the grating.

Mr. Mansergh's trap, made by Messrs. Doulton, is also a very useful invention. It is shown by *Figs.* 31 and 32.

Fig. 31.



Fig, 32



In this trap, it will be observed, two water seals are formed, and that between them an open communication to the air is afforded by means of a surface grating. By this arrangement when the pressure in the connecting sewer is sufficient to force the gas through the first or lower seal, it will escape into the air by the grating rather than through the second seal into the house. Mr. Mansergh's trap serves also as a grease trap, while the open grating admits of its serving as a yard gully. The socket marked "inlet" is the one to which the pipes from the inside of the house are connected; that marked "outlet" is for connection with the sewer. The socket marked "ventilator" admits of a ventilating pipe being attached and carried to the top of the house.

Figs. 33 and 34 illustrate the "Patent Stench and Grease Trap" of Mr. Dean, of Southam, in Warwickshire.

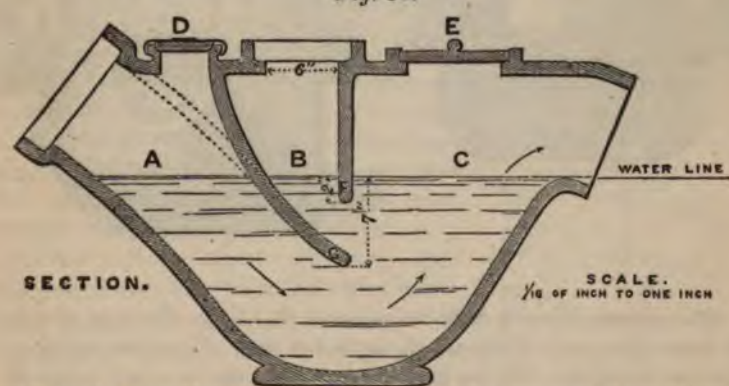
Fig. 33.

Fig. 34.

It is made of stone ware, generally round in shape, and either as a double (*Fig.* 33)—or as a single—trap (*Fig.* 34). It is provided with a movable iron receptacle or bucket B B, which facilitates the removal of the collected matter. The double trapping is effected by means of the seals or dips G and H, together with the plate EF, which forms the handle of the iron receptacle. The single trap (*Fig.* 34), however, is said to answer its purpose, and has been adopted in many instances with great success. The readiness with which the iron receptacle and its contents may be removed is a feature of recommendation.

Fig. 35 shows the excellent stoneware "Registered Interceptor Sewer Air Trap" of Messrs. Stiff, of Lambeth.

Fig. 35.



The air from the sewer is intercepted by means of two dips or water seals, F and G. Between these seals a means of ventilation is provided, which may be carried to the top of the house. Under ordinary circumstances the foul air will be confined to chamber C,

but should the pressure be strong enough to force the trap at F, the sewer gas will at once escape through the chamber B into the ventilating pipe. The second and *stronger* trap at G is said to effectually exclude all poisonous gases from chambr A, which forms the only avenue to the house. The diaphragm G is so constructed that the sewage from the house is discharged directly into the trapped chamber C, beyond the point of communication with the open air. By this arrangement the necessary ventilation of the trap is effected, with the *minimum* of contamination to the surrounding atmosphere. D and E are closely covered apertures for cleansing the trap, which is usually made with the latter opening only, but the aperture D can be added, if desired, for a small extra charge. When the house sewer is deep, a pipe should be conducted vertically from the opening E to about nine inches below the ground level, then carefully closed with the disc plate and covered with earth. By means of a long-handled ladle any subsequent obstruction in the trap may soon be removed without trouble or expense.

Figs. 36 and 37 show a trap known as Bavin's "Dip Trap":—

Fig. 36.

Fig. 37.

The makers, Messrs. Stiff, recommend that when this trap is used in areas and yards it should be provided with a cast-iron grating, ten inches square by one inch thick, which can be easily removed when necessary for cleansing or inspection. The grating should be kept about an inch below the paving level, so as to drain off the surface water.

Figs. 38 and 39 will explain the "Redhill Trap,"—also

manufactured by Messrs. Stiff—without any detailed description.

Fig. 38.

Fig. 39.

In the Bavin trap there is no ventilation of the discharging sewer with which it is to be connected, and as in that of Mr. Mansergh's and the Redhill trap, the liquid refuse enters under the grating instead of above it.

The invention of Mr. Rogers Field commends itself as superior to these on several grounds: first, it intercepts the coarser solid matters before entering the tank; next, it intercepts the kitchen grease and finer solid matters by an intermittent means of discharge, which allows a sufficient interval of time to elapse for the greasy water to cool and allow the fat to be completely separated; and, lastly, the sudden action of the syphon causes the liquid—after the solid has been deposited at the bottom of the tank—to discharge itself with a force sufficient to cleanse the sewer into which the liquid runs. I can speak from experience at my own house of the great utility of Mr. Field's invention, though I am prepared to find that the apparatus is a little too costly for smaller dwellings.*

There are numerous kinds of tanks and gully traps, the works of various makers, which are in use in yards and out-offices of dwellings for the trapping of communications with the sewer, and the interception of detritus and other solid matters. *Fig.* 40 shows one of a class very suitable for yards—that of Doulton. The trapping intended is dependent upon water being kept in the gully to the height of the dotted line. The detritus deposits itself at the bottom of the gully.

Fig. 40.

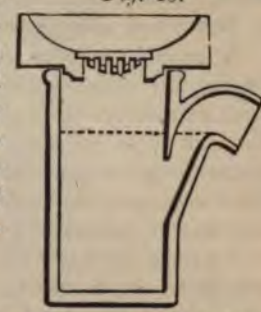
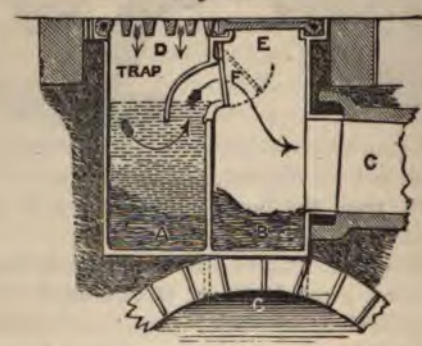


Fig. 41 shows also the stable or yard trap of Messrs. J. G. Stidder

* Since writing the above this apparatus has been made at a reduced cost.

and Co. The chambers A and B admit of the deposit of any solid matter—the latter to collect that which may escape from the first before the liquid reaches the communicating sewer C; and the trapping is affected by means first of a water seal or dip, and next by a valve, F, which opens and closes with the passage of the

Fig. 41.



water. The first chamber can be cleared of its contents by means of the grated inlet D, and the second by the cover E, which is rendered air-tight by a luted joint. If the trap is placed immediately over a large sewer as shown G, the second chamber becomes merely a means of communication with it, as shown by the dotted lines, in which case cover E is not needed.

These and other tanks and traps used in out-offices and yards are, however, all modifications—in some shape or other—of those used either in connection with the dwelling itself, to which I have already drawn attention, or of those used in the streets and roads of towns and villages, to which I shall hereafter refer.

In order to prevent any disagreable odour passing into the dwelling by the outlet pipes, it is necessary, even after the adoption of such outside arrangements as those which I have described, to have the sink pipes themselves trapped, for unless such precautions are taken the gases generated in the trap or sewer will be drawn into the dwelling by the greater warmth of the inside atmosphere, while the organic matter which collects and hangs to the inner sides of the outlet pipes will itself become a cause of nuisance as it putrifies. The simplest traps are the best for sink outlet pipes, and the more securely they are fixed to the sink, so that they cannot be put out of order or removed by servants and children, the more likely are they to answer their purpose.

Fig. 42 represents some very useful sink traps made by Messrs. Sutcliffe and Co., of Halifax. As will be observed, at the bend of the syphon, screws or small caps are provided for examination and for the removal of any stoppage that may occur in them.

Fig. 42.

Figs. 43 and 44 represent the "Patent Sink Trap" of Messrs. Tye and Andrews, of Brixton Road.

Fig. 43.

Fig. 44.

Figs. 45 and 46 show the "Registered Waste Pipe and Grating" of Messrs. Adams and Son, Haymarket, London.

Fig. 45.

Fig. 46.

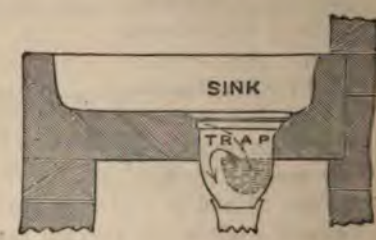
These, and such as are made on the same principles, are likely to supersede the old bell trap, which is practically found to be of little use in arresting the influx of effluvia by the discharging pipe.

Figs. 47 and 48 show the trap known as "Antill's Patent Trap." The dotted lines show the interior, the upper line representing a dip,

and the lower one the receptacle containing the water—the dip and the water constituting the seal or trap. The grating can be fastened down by a turn of the key shown.

Fig. 47.

Fig. 48.



Mr. George Jennings has contrived a sink to answer several purposes and dispense with the shallow water-traps which so frequently cause the evil they are intended to prevent. This sink comprises a housemaid's sink (see *Fig.* 49), and may be very usefully adopted in the upper floors of dwellings, where it will be found extremely appropriate for the discharge of bath and slop waters, if kept scrupulously clean.

Fig. 49.

LXII.—Scavenging and Dry Closets. The solid portions of the sewage of all well ordered dwellings, consisting of animal and vegetable refuse, dust, ashes, and the many other substances forming kitchen waste, as well as the excrementitious contents of outside

closets, require only careful collection and frequent periodical removal to render them free from nuisance.

If this work is performed by a public scavenger, under the directions of a sanitary authority in a country village, with proper facilities for collection, the duty may be thoroughly performed, but in the absence of systematic arrangement, evils will arise of the worst character. The necessity of well organized scavenging applies equally to the single dwelling as to towns and villages, and when it is remembered that at least four-fifths of the working population of this country still use middens, or privies, the importance of good scavenging will be acknowledged by every one. Pits and bins for the collection of animal and vegetable garbage, as well as for ashes and house sweepings, should be covered so as to keep out rainfall. If these conditions are not observed, the collection of such refuse becomes as bad, and has as injurious an influence on the air as privy cesspits and manure heaps, which it is now acknowledged on all hands should not exist in the proximity of dwellings. (See Section LXXXVII).

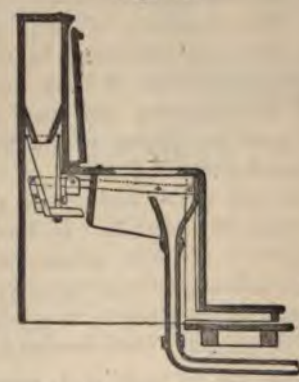
With the condemnation of leaky and overflowing cesspits, dry closets for the disposal of excretal refuse in rural districts are daily coming more and more into use in the place of common privies, while in the northern manufacturing towns, where "middens"—which have been declared to be "the standard of all that is utterly wrong"—are the common receptacles of the excreta of their inhabitants, great efforts are being made to introduce in their place moveable pails or boxes with disinfectants or absorbent linings.

The principle upon which the dry system of excreta removal is based is so well known that I need not describe it.

Many excellent forms of closet are now before the public, foremost amongst which stands that of the originator of the dry system, the Rev. Mr. Moule, whose invention, having been patented, has passed into the hands of a company, by whose instrumentality it is finding its way into general use. Dry closets are particularly suitable for the poorer dwellings of country towns, villages, and hamlets, where water is scarce and where water-closets would therefore be out of place. But there is no disguising the fact that the best dry closet is invariably associated with a vapid smell which becomes extremely objectionable when the closet is not kept properly cleansed. This condition is greatly due to the difficulty which is found in absorbing and deodorizing the whole of the urine by any of the materials used for the purpose.

To overcome this drawback Mr. Gibson, of Clapham, has invented a closet intended to separate the urine from the solid portions of the excreta, and allow the former to pass away by a distinct channel. *Fig.* 50 shows this closet and explains the arrangement.

Fig. 50.



The dry material may be either earth, ashes, or charcoal.

The patent closet of Dr. Bond, of Gloucester, is also designed for the separation of the urine from the fæces. The dry material (ashes or earth) is distributed over the fæcal matter by the shutting of the lid of the closet.

Mr. Parker, of Woodstock, and Mr. Morrell, of Salford, have each invented dry closets which have been favourably received.

The closet of Mr. Morrell is shown by *Fig.* 51, and is now being

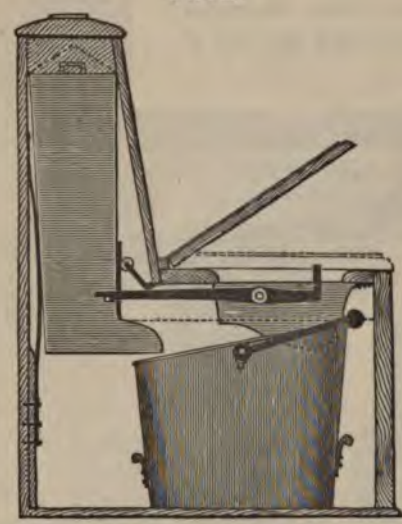
Fig. 51.

used at Salford and Manchester. It is called the "Self-acting Cinder-sifting Dry Closet."

The special feature in this closet is that the ashes from the house are thrown on the sifter through a hole in the wall at the side or back of the closet, instead of into the dust bin. The movement of the sifter is effected automatically when the closet is used, or rather the user of the closet effects the object without knowing it. The closet is so arranged that the sifter throws back the cinders for re-use in the house, while it delivers the quantity of ash-dust necessary to deodorize and absorb the fæcal matter into the pail below the closet seat each time the closet is used.

Fig. 52 shows another kind of dry closet made by Messrs King, of

Fi. 52.



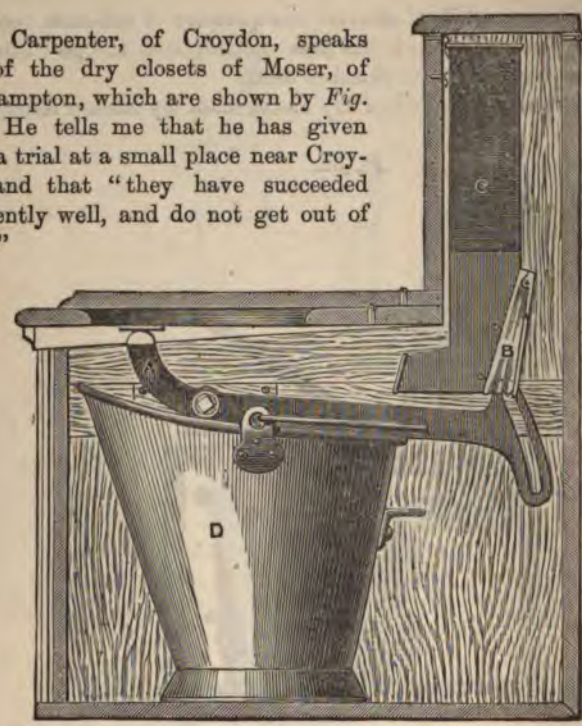
Moscow Terrace, Victoria Park, in which the dry material is distributed on the contents of the pail by the action of the lid, as in the case of Dr. Bond's closet.

The action of a closet-lid as a means of spreading ashes or dry earth upon excretal matter deposited under the seat commends itself to a mechanic, because the lid is easily capable of being connected with a rod running under the floor of the closet which could be made to throw out a bolt and so fasten the door of the closet when the lid is lifted up. By the same connection the closing of the lid may be made to withdraw the bolt and so allow the door to be opened, without which the person who has used the closet could not leave it,

and thus the covering of the excretal matter with the dry material will be ensured, in spite of the carelessness which so often prevails. I am not aware this has been already suggested by any one.

Fig. 53.

Dr. Carpenter, of Croydon, speaks well of the dry closets of Moser, of Southampton, which are shown by *Fig.* 53. He tells me that he has given them a trial at a small place near Croydon, and that "they have succeeded excellently well, and do not get out of order."



The closet is made to act by means of a spring seat, which, when used, moves the lever A, which acts on the bellows B, and throws a quantity of the dry material (ashes &c., mixed with sawdust, charcoal, spent dye woods, or dry earthy material contained in box C) over the contents of the pail D.

Several other forms of dry closets are in use in various parts of the country.

It is not, however, because the compound of dry earth and organic matter obtained by the use of these closets is commercially valuable that the dry system is gaining ground, for Dr. Gilbert, in the trials

made on behalf of the Sewage Committee of the British Association found that when ordinary field soil was used as the dry material the increase in the percentage of nitrogen was only ·015 each time the soil was used, and that even after being used twice it was not richer than good garden mould.

The advance of the dry system into public favour is therefore, on the whole, due rather to the difficulty of providing water than to the value of the product. A well arranged water-closet, with plenty of water at command, is always preferable to any earth closet that could be devised, so far as cleanliness and odour are concerned, though where circumstances prevent the supply of the requisite quantity of water earth closets have the advantage.

LXIII.—The Ventilation of the Dwelling. I think I have said enough in previous Sections (see Sections VIII., IX., XIV., and XV.) to show that as the air incumbent upon a free and aërated soil is invariably pure and wholesome, it is the duty of the Engineer to secure, by effective under-drainage, such a condition of the land upon which the dwelling stands as will ensure these advantages, assuming that, in cases where wetness or dampness exists, the nature of the subsoil will admit of the change.

The Engineer's duty may perhaps be considered to end outside the dwelling, by the provision of external air answering to the attainable standard of 20·96 per cent. of oxygen, and ·04 per cent. of carbonic acid, leaving it to the architect in designing the rooms and passages within the dwelling to secure an internal condition of atmosphere in which the amount of carbonic acid shall not rise above ·06 per cent.

It can hardly be the province of the Engineer to lay down any regulations for the guidance of the architect in the attainment of this object, though many of our most costly private and public buildings—notably the most recent erections in Whitehall—illustrate in a very conclusive manner how prejudicial to their occupation is the disregard of such considerations. As a general rule it may be stated that dwellings built on a dry soil, which maintain in their several apartments the full amount of air required for animal respiration and the combustion of fuel used in each apartment, and which is generally gained by properly devised doors, windows, and fireplaces, will maintain this standard without any special efforts at ventilation.

With these ordinary provisions the maintenance of pure air within the dwelling may generally be left to the natural laws governing the

diffusion of gases, the action of the wind, and the differences of temperature; though, to avoid draughts, it is often necessary to raise by artificial means the temperature of the in-coming air by admitting it through passages, or over surfaces which are heated, rather than directly from the open air. Richardson, who is an accepted authority on the subject, says: "In the ventilation and warming of a private dwelling, I would begin first with the staircase. This we ought to consider the principal artery of the house; and, if this were well warmed by a current of warm fresh air flowing into it, and a constant change effected by a ventilating outlet, warmed, so as to ensure its effective operation, great part of the business would be effected, as the staircase would supply all rooms not in use with warm air in a sufficient degree, and would gradually ventilate the whole building, rendering it unnecessary to have further ventilation, except in the principal living and sleeping rooms of the family."

The following observations* on the heating of air and water will be found useful when devising arrangements for the warming of passages and staircases by pipes.

"In order to raise one pound of water from 32° to 212°, the same quantity of heat is required as will raise four pounds of atmospheric air the same number of degrees." "So also, a pound of water in losing one degree would raise four pounds of air one degree.

"On comparing equal volumes the result is more striking; water is 770 times heavier than air, and a cubic foot of water in losing one degree of temperature would raise $770 \times 4 = 3080$ cubic feet of air one degree.

"If we note the time required to raise water from the freezing to the boiling point, or from 32° to 212°, through an interval of 180°, and then note the time required to boil away the whole of the water, it will be found to be $5\frac{1}{2}$ times that of the former; that is, if it require five minutes to raise the thermometer 180°, or from freezing to boiling, it will require $27\frac{1}{2}$ minutes to boil away the whole of the water without any rise of temperature. It is obvious therefore that during this time the water in passing into steam must have absorbed $180° \times 5\frac{1}{2} = 990°$, which is the latent heat of steam.

"One gallon of water converted into steam contains sufficient heat to raise $5\frac{1}{2}$ gallons from 32° to 212°. Hence, steam made to circulate in pipes through a building is an efficient and economical source of heat, one square foot of radiating surface in a steam pipe being, in

* *Warming and Ventilation*, by C. Tomlinson. Weales' Series.

general, sufficient for warming 200 cubic feet of space. No other vapour contains nearly so much latent heat as steam. A cubic inch of water at 212° becomes very nearly a cubic foot of steam at the same temperature, expanding as it does into 1696 times its volume."

The various contrivances which we see advertised for securing ventilation are only useful when a sufficient provision of air space, and a proper provision of inlets and outlets in the shape of doors, windows, fire-places, flues and shafts, are wanting. Every day's experience, indeed, clearly proves that refinements of ventilation are quite out of place in well-planned private houses, and need only be resorted to where large numbers of persons congregate in special apartments or buildings, or where the arrangements of a dwelling are defective, or where accident has defeated a good design. Every apartment from cellar to attic in a private dwelling should command the necessary circulation of air without the existence of draughts, which are equally resisted by the poor in the cottage and the wealthy in the mansion. The rural labourer will stop up with a whisp of hay the best patent ventilator his landlord may introduce, if by atmospheric attraction cold air rushes in to take the place of warm, and it makes him feel cold; while the wealthy nobleman will simply vacate one apartment for another if he is made uncomfortable from the same cause.

Without trenching on the province of the architect, it may be useful here to give, in addition to what I have already said (see Section III. under the head of *Air*), some further information as to the space required for the maintenance of health within the dwelling. Some of the figures about to be quoted will not, however, accord with those already given, nor with each other, the only positive inference to be drawn from them being that in every living room there should be a constant but imperceptible change of fresh for used air, in quantity proportionate to the number, age, and occupation of the inmates. The Engineer outside, and the Architect inside, should make the requisite arrangements for securing this circulation in ordinary dwellings, while in the case of special buildings in which an extra number of people congregate, the ventilation should be placed in the hands of an expert who has devoted his attention to ventilation under every condition.

The number of respirations which men on an average take in a minute is stated to be 20, and the volume of air inhaled each inspiration is equal to 40 cubic inches, giving 800 cubic inches as the volume per minute which is expired from the lungs after use. *(Tredgold)*. This volume is calculated by the same authority to

render unfit for being breathed a much larger quantity of surrounding air. The atmosphere of a *lighted* room containing several persons is directly and indirectly vitiated to such an extent as to require a supply of fresh air equal to four cubic feet per minute for each individual in the room. This quantity appears by the light of the researches of Dr. Parkes, Dr. De Chaumont, and Dr. Angus Smith, to be altogether inadequate.

The cubical space considered by certain recognised authorities to be necessary to afford dilution, and so correct the air-vitiation of public buildings, varies in a manner impossible to reconcile. For instance, the cubical space considered to be a right provision in the case of schools erected by the London School Board is 130 cubic feet per scholar; that for dormitories under the Metropolitan Lodging Houses Act is 240 cubic feet per head, while that allowed by the Poor Law Board is 300 cubic feet per head for healthy persons in dormitories, and in English barracks the space considered to be right is 400 cubic feet, per man, in wooden huts, and 600 cubic feet in more substantial structures. Eight hundred cubic feet per head seems to be, however, the usual space required in middle-class houses; while in hospitals where, for obvious reasons, an increased space should be given, the allowance varies from 1,000 to 1,500 cubic feet per person. In the building of labourers' cottages on all well-managed estates in this country, the recognised cubical space of living rooms is 1,200 feet, of parents' bedrooms 900, and of children's bedrooms 675 cubic feet.

Perhaps the most useful rules that can be recorded as to the quantity of external pure air which should pass per hour, per head, through a room, in order to keep down the carbonic acid to the accepted ratio already given, are those which are furnished by the late Dr. Parkes in his *Practical Hygiene*, in a table, from which the following figures are taken :—

Amount of cubic space provided per person.	Amount of air necessary to dilute to a standard of ·06 per 100 (or ·04 initial carbonic acid, and ·02 respiration) during the first hour.	Amount necessary to dilute to same standard after the first hour.
Cubic Feet.	Cubic Feet.	Cubic Feet.
100	2,900	3000 in each case.
200	2,800	
300	2,700	
400	2,600	
500	2,500	
600	2,400	
1,000	2,000	

How is this mixture of fresh air with the vitiated air to be accomplished? Carbonic acid gas is heavier than atmospheric air, and expired air is rather lighter than the air of a room under ordinary conditions. This is due to the existence of nitrogen and vapour both of less specific gravity than air, and the higher temperature of the breath and the emanations of living bodies. These conditions give to vitiated air the buoyancy which takes it to the upper part or ceiling of a room, and point to the latter as the proper place for the outlet. The outer and cooler air, whether admitted from the open space surrounding the dwelling, or from passages existing in it, should come in from a level as low as circumstances will admit without causing a draught, and to assist in the circulation and dilution of air, when doors, windows, and fire-places fail in that duty, it would appear desirable to build in union with each stack of chimneys an air shaft (empty chimney) to serve the single purpose of ventilation. In this shaft valves may be inserted to rid each chamber on the different floors of the heated and vitiated air. The warmth of the air maintained in the shaft will assist the ventilation without risk of nuisance from smoke and dirt which so often attends the introduction of valves into chimneys.

Mr. Eassie, in his valuable treatise on *The Sanitary Arrangements of Dwellings*, relates a very interesting experiment made by Dr. Russell, of St. Bartholomew's Hospital, to ascertain the temperature of different parts of a room of which the doors and windows were of the ordinary kind. The experiment was tried with both doors and windows closed, and with a fire and three gas burners alight. The size of the room was 13 feet × 15½ feet, and 10½ feet high, and two persons only were in it, and this condition, it was assumed by Dr. Russell, was exactly the same as that of thousands of houses during the winter season. After three hours has elapsed the temperature at nine inches below the ceiling had risen 17½ degrees, at five ft. above the floor line it had risen 15 degrees, while at the floor line it was four degrees only above the temperature recorded before the doors and windows were shut, and when the room was filled with fresh air. From this it will be seen that in any arrangenents made for the removal of vitiated air, and the admission of fresh air, it is necessary to have regard to the conditions which rule the temperature of the room.

The removal of vitiated air from, and the regulation of the temperature of, public buildings, such as hospitals and asylums, and of private mills and factories, and the dormitories of large institutions and private dwellings, are, as already stated, objects of extreme

difficulty. Up to this time science has certainly not been able fully to master the subject, although a great number of valuable theories have been propounded by experts, and ingenious inventions brought forward.

Among them certain contrivances aiming at the creation of a constant "up" or "out" draught from ventilating shafts, pipes, and tubes, and from chimneys and sewers, by directing a current of air (wind) across the top of them, appear likely to be attended with success, and may be usefully applied in ordinary dwellings. Some of these are figured on *Drawing* IV., and the principle involved is called ventilation by "extraction." The action of Banner's cowl (*Fig.* 3 on *Drawing* IV.), which well illustrates the principle, is thus described in *Blyth's Dictionary of Hygiene.* "The large end of a funnel-shaped tube is always directed towards the wind, and a current of air passing in there, is pressed forward through the annular space between the two cylinders. When it reaches the end of the inner one, it expands round it, and in its passage out at the smaller end a vacuum is created round the point of the inner cylinder which, by suction, draws out its contents into the open air."

I cannot speak of the value of this contrivance from my own personal experience.

Three other ventilators are shown upon *Drawing* IV. *Fig.* 1 represents that known as Boyle's "Air-Pump Ventilator." *Fig.* 2 represents Howarth's "Archimedian Screw Ventilator," and *Fig.* 4 shows Landau's "Automatic Ventilating Cowl." Like the ventilator of Banner, already described (*Fig.* 3), those shown by *Figs.* 1 & 4 aim at the creation of a cross draught of air at the top of the shaft or opening intended for the escape of foul air. In the case of *Fig.* 4, however, this object is sought without the revolution of any part of the contrivance in accordance with the direction of the wind.

LXIV.—The Water Supply of the Dwelling. In all districts where the supply of water is obtained from a source in the hands of a sanitary authority or a public company, the occupants of dwellings will generally do well to accept that supply, instead of looking for one of their own, for the instances are rare in which a better or safer one can be obtained from private sources. Moreover, if the actual cost of water obtained by means of a general supply be compared with that derived from private sources, it will be found that, in the majority of cases, the former will be the cheaper of the two. Where a general or combined supply is adopted in rural parishes or districts, the population of which is sparse and

Fig. 4.

School of Military Engineering, Chatham.

comparatively poor, it is just possible that the annual charge on private dwellings, which, on an average, reaches 1s. only, may reach 1s. 6d. in the pound on their rateable value. A dwelling of which the rateable value is £100, would then be charged as much as £7 10s. per annum, or nearly 5d. per day, which is high, though not too high to deter householders from taking it at the price; but supposing the quantity of water consumed daily in such a dwelling to be 300 gallons, the charge would then reach a penny per 60 gallons delivered to the premises. It is impossible to deny that though this rate of charge very much exceeds that of large towns (see Section XIX.), it would be very much less than a resident of such a dwelling in the country expends in pumping, or otherwise providing the same quantity of water for the use of his establishment.

These remarks, which favour combined supplies in rural as well as urban districts, do not, of course, apply to dwellings held with lands of an extent and character sufficiently large to furnish water from springs or from uncultivated surfaces, and to allow of its delivery by gravitation. They refer to those very numerous instances where no general supply exists, and where individuals are dependent on wells or rivers, or upon surface waters to be collected and stored in tanks.

When treating in my previous remarks on *Water* generally, I endeavoured to show that the Engineer, however closely he may agree with the chemist in his abstract views of the different qualities of water, must, in a majority of cases, disregard—because he cannot command—those sources which the chemist prefers, and have regard to those waters only which are within his reach, even though they may be such as have been characterised as "suspicious."

(1) *Wells of Various Depths.* Up to this time, in nine out of ten cases where no general supply exists, the occupants of dwellings are dependent upon wells of different depths. These are generally called either "Deep Wells" or "Shallow Wells."

"Deep Wells" are technically understood to mean wells of any depth, which reach a subterranean bed in one of the water-bearing strata, and which, being fed by wide and distant conrtribution, never altogether fail in supply. In the majority of cases the power required to raise the water of such wells is greater than that of hand.

"Shallow Wells" are those which are fed by land or surface springs from sources of limited extent which may fail in very dry

weather, and the waters of which are frequently raised by hand by a suction or atmospheric pump.

Between these two characteristic kinds of wells there are others which penetrate a greater depth than "shallow wells" without reaching a water-bearing stratum. The waters of these wells are raised by lift and force or centrifugal pumps, or by windlass and bucket. They are sometimes called deep wells, because the common suction pump is insufficient of itself to raise the water, though they more frequently than either "deep" or "shallow" wells fail in supply. They are as liable to defilement as the latter, while they are not benefited by the dilution due to the large body of water forming the supply of wells sunk into the water-bearing strata. The following monthly record of the depth of water in one of these wells (at Stevenage, Herts), extending over two years and a quarter, will show how the supply varies with the rainfall of somewhat distant periods, and how little they can be relied upon as an available source for all times :—

Month.	Rainfall during month.	Total rainfall of the 12 months immediately preceding.	Depth of water in well at beginning of each month.	Month.	Rainfall during month.	Total rainfall of the 12 months immediately preceding.	Depth of water in well at beginning of each month.
	Inches.	Inches.	Ft. In.		Inches.	Inches.	Ft. In.
1872				1874			
October.....	3·730	—	—	September	3·118	18·255	4 0
November	3·430	—	—	October ...	2·513	18·930	3 5
December...	3·780	—	—	November	1·956	19·096	2 8
1873				December	2·222	18·377	1 11
January ...	3·025	—	—	1875			
February ...	1·907	—	—	January ...	2·293	20·028	1 7
March	1·718	—	—	February	·973	20·721	1 3
April	·893	—	—	March	·778	20·231	1 2
May	2·186	—	—	April	1·543	20·296	1 1
June	1·749	—	—	May	2·213	20·047	1 11
July	2·013	—	—	June.....	2·895	21·537	1 11
August	2·281	—	—	July	5·947	23·036	1 11
September	2·443	—	—	August ...	1·202	27·628	1 11
October.....	2·397	29·215	—	September	2·458	27·303	1 11
November	2·675	27·882	—	October ...	3·937	26·643	2 1½
December...	·571	27·127	—	November	3·722	28·067	2 4
1874				December	1·037	29·833	3 0
January ...	1·600	23·918	7 6	1876			
February ...	1·463	22·493	6 10	January ...	1·860	28·998	4 2
March	·713	21·989	6 2	February	2·380	28·565	5 2
April	1·792	20·984	5 10	March	2·970	29·972	6 0
May	·723	21·883	5 5	April.....	2·810	32·164	7 3
June	1·396	20·420	4 9	May	—	—	7 10
July	1·355	20·067	4 8½				
August	1·527	19·409	4 0				

I introduce this table, which I have prepared as a record of local hydro-geology, that you may see how the autumn and winter rains govern subterranean supplies such as this well illustrates, and that you may observe the fact that unless the summer's evaporation has been compensated by copious rains in September, October, and November, followed by an average winter's rainfall, such wells may fail altogether.

The foregoing table shows that the wet winter of 1872-3 (17·65 inches) followed by a summer rather wetter than usual (11·56 inches) had raised the water in the well to such a height that on 1st January, 1874, it stood 7ft. 6in. deep. The winter of 1873-4 was a dry one (9·42 inches), and was followed not only by a dry summer (9·91 inches), but by another dry winter (1874-5—10·73 inches), the consequence being that the water in the well was only 1ft. 1in. deep in April, 1875, and none could be drawn from it. At the present time, owing to the wet winter of 1875-6 (15·90 inches), following a wet summer, the water in the well has not only recovered its depth (7ft. 10in.), but at this moment (May, 1876) it is still on the rise. The depth of the well is 78ft., and it is sunk in the drift overlying the chalk.

At the present time, when the supply of pure water is regarded with the greatest interest, as the first essential of life, such information as this table affords will be found valuable, for it must remove the impression that has prevailed that wells of such medium depth are more to be relied upon than shallow wells, which are often replenished by the accumulation of rains, from which the deeper wells derive no accession of supply.

Deep Wells. — In the case of large establishments and public institutions, it will be necessary to have at command a supply of water, if it can be possibly secured, which will not be readily affected by diminished rainfall; and the instances are few in which either the new red sandstone or the chalk will fail, unless the subterranean bed is being drawn upon at the same time by large communities. (See Section XXXII. and Appendix F.)

Referring you back to Sections XXIV., XXV., XXVI., and XXXII., for the analyses and characters of deep well waters, I may here give the opinions of the Rivers Pollution Commissioners of the waters to be derived from the new red sandstone and the chalk, which possess larger water-bearing capabilities than all the other formations of the crust of this country put together. They say that "unpolluted waters drawn from deep wells in the *new red sandstone* are almost invariably clear, sparkling, and palatable, and are among

the best and most wholesome waters for domestic supply in Great Britain. They contain, as a rule, but a moderate amount of saline impurity, and either none, or but the merest traces, of organic impurity. The hardness is usually moderate, and only when the water is derived from originally impure sources does it become excessive. There is every reason to believe that a vast quantity of hitherto unutilized water of most excellent quality is to be had at moderate expense from this very extensive geological formation." * * * * "The unpolluted deep well waters from the *chalk* rank amongst the best and most wholesome with which we have become acquainted. They are almost invariably colourless, palatable, and brilliantly clear. The chalk constitutes magnificent underground reservoirs, in which vast volumes of water are not only rendered and kept pure, but stored and preserved at a uniform temperature of about 10° C. (50° F.), so as to be cool and refreshing in summer, and far removed from the freezing point in winter. It would probably be impossible to devise, even regardless of expense, any artificial arrangement for the storage of water that could secure more favorable conditions than those naturally and gratuitously afforded by the chalk, and there is reason to believe that the more this stratum is drawn upon for its abundant and excellent water the better will its qualities as a storage medium become. Every 1,000,000 gallons of water abstracted from the chalk carries with it in solution, on an average, one-and-a-quarter tons of the chalk through which it has percolated, and thus makes room for an additional volume of about 110 gallons of water. The porosity or sponginess of the chalk must therefore go on augmenting, and the yield from wells judiciously sunk ought within certain limits to increase with their age. The only drawback to these waters is their hardness, but this disadvantage is greatly reduced by the circumstance that it is chiefly of the 'temporary' kind, and can be therefore easily and cheaply removed by the application of Clark's process." (See description of this process, Appendix G).

These tempting words of the Rivers Pollution Commissioners must be received with considerable allowance. We must not forget that both the water in the chalk below London, and that in the new red sandstone below Liverpool, have sunk permanently 50 feet, if we are to believe the evidence referred to in Section XXXII.

The well-sinker, moreover, does not always meet with a sufficient supply even in these strata. In the chalk he will occasionally fail altogether in reaching any supply, while in several instances the

draught of certain wells has been known to seriously detract from the supply of others. (See Section XXXII. and Appendix F.)

When sinking very recently the trial-shaft at St. Margaret's Bay, to ascertain the condition of the earth through which the proposed channel tunnel would pass, Mr. Tilley, of Walbrook, bored through the chalk and green sand formations into the gault *without finding any water*. In the new red sandstone there has been experienced, in addition to occasional failures of supply, the disadvantage arising from the existence of gypsum, which gives an excessive degree of hardness to the water, while in some of the beds of the same formation salt prevails to such an extent as to render the water altogether unfit for domestic purposes.

As an Engineer seeking water from subterranean sources must have reference to the geological features and the special circumstances of each particular case, I will content myself by referring very briefly to some executed works, the particulars of which may be found useful.

In the new red sandstone Messrs. Mather and Platt, of the Salford Iron Works, have done much in gaining water with their patent rock boring machinery. The yields afforded by some of these borings are set forth in the following table :—

Locality.	Diameter of bore.	Depth bored.	Supply of Water per day of 24 hours.
	inches.	feet.	gallons.
Hulme, Manchester	13	259	86,400
Stockport ,, ...	12	348	50,000
,, ,, ...	12	228	43,200
Cheadle ,, ...	12	145	55,200
Patricroft ,, ...	12	292	100,800
Macclesfield	12	94	66,240
Stockport, Manchester...	12	182	34,560
,, ,, ...	12	192	24,960
Hulme, ,, ...	12	189	46,080
Warrington	9	348	63,360
Winwick, Warrington	18	212	461,000
Manchester	18	454	648,000
Manchester	15	466	570,000
Stockport, Manchester	18	424	806,400
Cardiff, South Wales	18	248	720,000
Manchester	12	312	93,720

By way of parenthesis I may here state, in proof of the *rapidity* with which borings may be effected by Messrs. Mather and Platts' machinery, that at Nottingham a depth of 374 ft. with a 12-inch bore-hole was reached in 91 days; though this rapidity hardly bears comparison with that with which the Abyssinian tube wells (see *Figs.* 54 to 57) have been driven in different localities

At Brussels a depth of 60 feet was reached in two hours, while at Mr. Warren de la Rue's Observatory, two wells ($1\frac{1}{4}$ in. diameter) were sunk to a depth of 30 feet in one day, the yield of water obtained being 900 gallons per hour. At this place (Chatham) Messrs. Le Grand and Sutcliff, the makers of the tube well, have driven 81 feet in one day; and at the Cattle Station, Thames Haven, 51 feet have been reached in the same time. The late Emperor of the French personally assisted in the operation of driving one of the Abyssinian tube wells at St. Cloud, when 28 feet were driven in half-an-hour.

Mr. Tilley, who has had much experience in well sinking and boring in different formations, has given me the results of some of his operations in the chalk and the new red sandstone. Speaking of the latter he says that at Aston, near Birmingham, he sunk a well 100 feet deep and bored 300 feet for the Birmingham Water Company, and obtained a supply equal to 3,000 gallons a minute, or nearly 4,500,000 gallons daily. The bore-hole is 20 inches in diameter, and into it the suction pipe of the pump descends. The pump works a 10-ft. stroke at the rate of $9\frac{1}{2}$ strokes per minute. In this instance Mr. Tilley tells me that the water stands at a constant level, not varying a quarter of an inch even when the pumping is continuous.

The same well-sinker has executed sundry other works with different results. In 1861 he sunk, at a cost of £2,300, "No. 1 well" for the Wallasey Commissioners. It was seven feet in diameter and 90 feet deep and was lined with cast iron cylinders. A boring was made at the bottom of the well partly 14 inches and partly eight inches in diameter to a total depth from the surface of 250 feet. 24 hours pumping at the rate of 500 gallons per minute reduces the head of water 51 ft. 9 ins. In 1873 he sunk a similar well, known as "No. 2 well," about 20 feet distant from No. 1, and made an 18-inch bore-hole to a depth of 400 feet from the surface at a total cost of £2,677. The quantity raised from this well is 700 gallons a minute. Since the well was finished No 1 yields a greater quantity of water than before, and the commissioners—Mr. Tilley tells me—are enlarging and deepening it to the depth of No. 2.

At Eaton Hall, near Chester, the seat of the Duke of Westminster, Mr. Tilley has lately made a six inch bore-hole, 350 feet deep, which at 28 feet from the surface yields 200 gallons per minute. The boring cost 20s. per foot with 12s. 6d. per foot added for piping.

Returning from the red sandstone to the chalk, I may state that at the extension works of the Dockyard here (Chatham), a well was

sunk 70 feet deep and lined with cast iron cylinders, from the bottom of which a bore-hole lined with 18-inch cast iron pipes was further sunk to a depth of 58 ft. 6 ins., followed by a 12-inch boring 163 feet further still. From this well large quantities of water are obtainable. The supply at 39 feet below the coping of the new basin has been guaged and found to yield 1028 gallons per minute (nearly $1\frac{1}{2}$ million gallons per diem). The water when at rest stands at a level of 18 ft. 6 in. below the same datum, or 20 feet higher than the pumping depth.

It may be mentioned that the Chatham Water Works Company derives its supply from the chalk formation at a village (Luton) under the Star Hill from driven headings.

Perhaps one of the best examples that could be given of the quantity of water which may be obtained from the chalk for a large dwelling, or for a small community, is that afforded by Mr. Tilley's experience at the Mercers' Mill Brewery, Uxbridge, where a bore-hole yields a supply of a true artesian character. The bore-hole is four inches in diameter and the depth 130 feet. The water rises from the hole to a height of $4\frac{1}{2}$ feet above the surface at the rate of 70 gallons a minute, and is sufficient to work a ram which could raise into the brewery a proportion of the outflow quite equal to the quantity required. The cost including 80 feet of piping was £133.

At Woolwich a well has been sunk 580 feet deep, on a site $22\frac{1}{2}$ feet above mean sea level, the yield of which had been 1,400,000 gallons per diem. Another well has been sunk 160 feet at Brompton, on a site 152 feet above mean sea level, and the yield has been nearly 300,000 gallons per diem. At the London Orphan Asylum, at Watford, on a site 190 feet above the mean sea level, a well which was sunk 257 feet into the chalk, yielded 80,000 gallons a day.*

I have obtained some valuable information in the form of the following table from Mr. Paton, of St. Albans, whose name is associated with the efforts made to supply London with water from the Colne Valley, and who has had very large experience in this kind of work :—

* From *Waterworks*, by S. Hughes. Weale's Series.

WELLS SUNK AND BORINGS MADE IN THE CHALK FORMATION.

	Depth.			Length of headings.	Size.			Daily yield in gallons.	Cost of sinking, boring, &c., including materials used.
	Sunk.	Bored.	Total.		Sinking.	Boring.	Headings.		
	ft.	ft.	ft.	ft.	ft. in.	ins.	ft. ft.		£
Luton Waterworks	50	272	322	—	6 0	10	—	200,000	405
Edgware Public Well...	90	200	290	—	4 0	7	—	40,000	250
Harrow Waterworks	193	210	403	—	6 0	15	—	200,000	1940
Henley-on-Thames	246	234	480	—	5 6	6	—	40,000	480
High Wycombe Waterworks ...	—	171	171	—	—	10	—	120,000	238
Temple Mills, Great Marlow ...	20	395	415	—	6 0	12	—	700,000	525
Watford Brewery, Watford ...	6	227	233	—	5 0	7	—	135,000	250
Commercial Travellers' School, near Pinner	32	110	142	—	4 6	6	—	60,000	150
Hendon Union	85	240	325	—	4 6	7	—	50,000	310
Guildford Union	210	124	334	—	5 0	6	—	40,000	327
Berkhampstead Waterworks ...	10	200	210	—	4 6	8	—	100,000	200
Earl Brownlow's Estate, Ashbridge	255	90	345	323	6 0	10	7 × 6	288,000	2099

The last instance given in the foregoing table has a special bearing on the water supply of the dwelling, as it shows what a nobleman of wealth may do for the supply of his mansion, and for farms and villages near at hand. In this case I am informed by Mr. Paxton, the agent to the estate, that the water is raised by an engine of 28 horse-power, working three-throw pumps, in sufficient volume to afford a constant supply to the mansion, gardens, and fountains, as well as to the villages and farms of Ringshall, Little Gaddesden and Hudnall. The total cost of laying on the water—including well sinking and boring, engines, covered reservoirs, tanks and cisterns—was £11,018 18s. 8d., while the average cost of repairs, attendance, and working expenses, amounts to £430 per annum.

Mr. Thomas Docwra, of Balls Pond, who has also had very wide experience in well sinking, says that he has found that many beds, both in the new red sandstone and in the chalk, differ very much in texture, as well as in their other characteristics. There are layers, he says, in the chalk quite as compact and solid as certain descriptions of rock; some beds, in fact, being used as a building stone. These are costly to get through. Comparing the soft with the hard portions, Mr. Docwra says the cost of excavation will be about half. With respect to the new red sandstone, he considers that, as a general rule, the cost may be taken to be about double that of the same work in the softer chalk, or about the same as the harder chalk. The cost of sinking wells—say of a diameter of seven feet—in the soft chalk is estimated by Mr. Docwra at 20s. per foot for the first 20 feet, to

which must be added 5s. per foot for each 20 feet of additional depth; for instance,

Wells from 20 to 40 feet in depth, 25s. per foot.
Do. 40 to 60 feet „ 30s. „

With respect to boring, Mr. Docwra's figures are as follows:—

24-in. bore-hole, without piping, starting at 100 ft. from surface.			20s.	per foot, increasing 3s. per foot at every 20 feet.	
18-in.	„	„	16s.	„	2s. 6d. „
12-in.	„	„	10s.	„	2s. „
6-in.	„	„	8s.	„	1s. 6d. „

and he states that "the prices of cast and wrought iron pipes for lining bore-holes, vary from 1s. per inch (diameter) per foot in the smaller sizes, to 1s. 6d. per inch per foot in the larger sizes. In driving headings in chalk the cost is governed by the depth from the surface; one at 100 feet, of the size of seven feet by four feet, would cost £2 to £3 per foot forward." These figures do not include any pumping that may be requisite during the carrying out of the work.

Mr. Tilley puts the cost of boring in the red sandstone and in the chalk as follows:—

	Red Sandstone.	Chalk.	
6 inch bore hole,	... 20/-	... 20/-	Exclusive
12 inch „	... 40/-	... 32/-	of
18 inch „	... 60/-	... 54/-	pipes.

Supplies of water in large quantities and of excellent qualities may be also obtained by the sinking of wells in other strata, besides the new red sandstone and the chalk. (See Section XIX.)

The Rivers Pollution Commissioners refer to the water obtained from the oolites, as "bright, sparkling, and palatable," and state that "if the original water feeding these wells has not been grossly polluted, the quality of the oolitic deep well waters is most excellent for drinking and all domestic purposes, except washing." This formation, it will be remembered, runs in a long strip from the North to the South of England, and has been resorted to for water in various places. At Northampton the supply reaches 500,000 gallons a day, or 12 gallons a head, and is declared to be of superior quality. An instance of a supply from this source is given in the table in Section XIX.

Deep wells have been sunk in the old red sandstone as well as in the Hastings sand, the lower and upper green sand, and in the Wealden formations, with great success, but the quality of the water is not generally so good as that obtained from the strata to which I have specially referred.

The coal formation, with its beds of porous grit and sandstone, alternating with retentive strata of shale and clay, is found also to yield water in quantities sufficient for large establishments and isolated dwellings. These waters, though generally palatable, are liable to have a slight chalybeate taste. They also in some places contain rather large quantities of saline matter in solution, and well sinking in this formation is therefore attended with great uncertainty.

Speaking generally, not only is the sinking of deep wells an expensive and, in some instances, a doubtful work in itself, but when the annual cost of pumping is added to the interest on the capital expended, the current cost often becomes a very formidable matter indeed. In large towns the expense of obtaining water from deep wells falls comparatively lightly upon the recipients, the number of inhabitants upon which it can be apportioned being large. If we refer back to the details given in table Section XIX, we find that the charge for water reaches five per cent on the rentals of houses in a large number of the instances quoted. For the supply of single dwellings even of a large size, the annual cost of pumping, with interest on the original outlay added, too often greatly exceeds this. We find, too, in practice, that after great expense has been incurred in sinking deep wells, the labour of pumping, where neither steam, water, wind, or horse-power, is resorted to, is so oppressive on servants, that the only water raised is that used for drinking and special purposes. Deep wells are then supplemented by shallow ("suspicious") ones, or by the storage of surface waters (also "suspicious"), so that the superior character of deep well water is partially lost, and the original outlay increased by the provision of two sources of supply.

Shallow Wells.—On this head I would refer you to my previous observations on the subject of shallow wells (Section XXXIX.), in which I spoke of their value when free from surface drainage, and explained a means of recovering their use in rural districts, after a perfect means of sewerage has been carried into effect, and a proper system of scavenging organized, whereby the chances of contamination have been reduced to a minimum. I would add here, that wherever a constant supply of pure water can be found

in a free soil within 20 or 25 feet of the surface, recourse may be very advantageously had to the Abyssinian (Norton's) tube wells. (See *Fig.* 54.) If these tube wells are adopted no shaft is sunk. The water is reached by driving or simply screwing the tube down through the ground to the water level. In localities where the water reached is below the range of a lift pump, it is necessary to employ tubes of a larger diameter than those adapted to shallow wells, and the plan by which the water is raised from any depth, is described by Messrs. Legrand & Sutcliff, the makers of the Abyssinian well tube, in the following terms:—

Fig. 54.

Fig. 55.

Fig. 56.

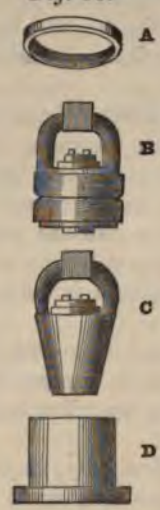


Fig. 57.

"As soon as the first or pointed length has been driven, a working barrel, which consists of a short length of well tube lined with brass, is added to the well tube by placing the valve seat D into the working barrel (which is engraved in section in order to show the position of the lower valve seat and ring—see *Fig.* 55), and then screwing the working barrel on the well tube in the usual manner with the socket which has been taken off the well tube, until it fairly butts upon the well tube.

"The ring A, with its broad part downwards, is next laid on top of the working barrel, as shown in *Fig.* 55, on to which the next length of tube is screwed in the ordinary way until it is firmly butted on to the working barrel, after which process driving is continued in the ordinary manner until water is reached, and when driven until there stands several feet of water in the tube, the lower valve C is lowered into its seating by means of a small hook provided for that purpose, which can be coupled to the pump rods.

"The lower valve having been carefully wound round with tow and a little tallow, is hung on to the hook above mentioned, and thus lowered down the tube until it reaches the valve seat D, as shown in *Fig.* 57; the hook is then disengaged from the valve and drawn up.

"The bucket B is next screwed on to one of the iron rods provided for the pump, and lowered down the tube well by adding as many of the rods as are necessary, until it reaches into the working barrel, as shown in *Fig.* 57, and by allowing it to rap very slightly on to the lower valve C it will embed the lower valve firmly into its place.

"The rods that have been thus lowered have now to be coupled to the short length connected with the pump handle and passing through the barrel, the best way to do this being to remove the pump handle, when the short rod leading from it can be screwed into the coupling, and made secure like the rest of the joints by split pins. The pump head can then either be screwed or bolted on to the tube well, and when the handle is connected the whole is so far complete.

"To start the pump, water must be poured down through the top, and pumping commenced, and in a short time the water will commence to flow, the time varying according to the depth it has to be raised.

"At first it should be pumped rapidly, in order to get up as much of the grit and sand as possible, until it gets clear, and as soon as this is done the well is complete.

"In conclusion it may be observed, that all remarks and instructions given for the smaller wells, apply equally to the larger and deeper wells.

"A simple plan very frequently adopted with deep wells, where the depth at which the water stands is not very much below the reach of a lift pump, is as follows:—For instance, when a tube well has been driven, say 50 feet, and the water has risen only 12 feet, a hole, say 12 feet, can be dug, at which depth

the ordinary pump can be attached, and the well cleared up, and then a working barrel can be coupled on with a larger tube reaching to the surface, and surmounted by a pump head, as described. This large tube can be of either wrought or cast iron, and as the lower valve, &c., can be got at from the surface, the hole can be filled up again.

"It will be seen that this plan will frequently be found the most economical, especially where it is not known beforehand that the water will require to be raised from such a depth, as it enables the small tube that has been driven to be utilized, instead of having to pull it up, and re-drive another larger and more expensive tube, besides the delay thereby incurred.

"When water is required in large quantities, either for public establishments, factories, breweries, or for irrigation, two or more of the first, second, or third sized wells are driven, and coupled together to one main, according to the supply required and the nature of the strata from which the supply is obtained.

"No rule whatever can be laid down as to the number or size of tube wells necessary to be driven in order to obtain a given quantity of water, for everything depends upon the nature of the water-bearing strata. In some places water may exist in abundance, but the stratum may be of a close, unyielding nature; in other places the water-bearing seam may be but shallow, and yet supply a copious yield, and in others both the seam may be shallow and the yield slow, and *vice versâ*.

"The smallest size tube well ($1\frac{1}{4}$-inch) is of course the most handy, and when the supply required is not very large, it may be more convenient to couple as many as four or five together, though this remark refers more particularly to when the wells are sent to colonies and great distances, where it would involve considerable delay to send for the larger sizes. The average $1\frac{1}{4}$-inch well will yield from 150 to 800 gallons per hour, according to the nature of strata and power applied.

"The second size (2-inch) is a very useful one, and can at times be used with advantage to the number of 10 or 12 coupled to one main, the capacity of yield being from 300 to 1,500 gallons per hour, according to the nature of the stratum, &c.

"The third size (3-inch) is the description mostly employed for large supplies, and on an average will yield from 450 to 2,000 gallons per hour.

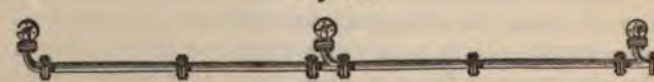
"It should be mentioned that in localities where the yield is found to be slow, and the water-bearing seam shallow, it is

sometimes an advantage to employ a larger number of small wells in preference to a lesser number of large wells, inasmuch as if the rate of supply will not exceed a given maximum quantity to one centre, the employment of larger wells will not increase such yield proportionately with the increased size.

"The manner in which a number of these wells are usually coupled together is by means of a main, or series of cast iron flange pipes with branch pieces placed at intervals, such intervals being governed by the nature of the water-bearing seam. Usually it is found that 18 feet of main is a fair space to place between the branch pieces in order that the draught of one well may not interfere with that of the next. There are of course places where it would be safe to place them nearer together, whilst on the other hand there are places where it may be necessary to increase this distance. As a rule the further apart (within reason) the better.

"As will be seen by *Fig.* 58, a bend is attached to each branch

Fig 58.



piece, and this bend is coupled on to the tube well by means of a flange screwed on to the tube well corresponding with the flange of the bend.

"More wells can always be added to this main at any time by simply substituting a branch piece for the terminal bend, and prolonging the cast iron pipes in accordance with the number of wells added, and again finishing with the original terminal bend.

"For convenience and protection from frost it is customary to lay these mains two feet below the surface. The flange joints are usually made with india-rubber washers."

The makers of these tube wells state that in gravel, chalk, and some kinds of hard marls, from 400 to 2,000 gallons of water per hour may be obtained by their use, the ordinary quantity in coarse sands ranging from 300 to 800 gallons per hour, and in fine sands (including quicksand and loamy sand) from 150 to 500 gallons per hour. At Burton-on-Trent where the coupled tube wells to which I have just referred—and which are shown by *Fig.* 58—are in use, and where the subsoil is composed of a gravel and sand, two of the principal brewers raise from 40,000 to

60,000 gallons per hour each. At Northfleet (cement works) 3,000 gallons per hour are thus raised from the chalk, and at Newark 4,000 gallons per hour from the red marl formation. There is no reason why such a safe and economical means of supply should not be more frequently resorted to for dwellings of all kinds where the water stands in the ground within a moderate distance of the surface.

Fig. 59 shows a tube well and centrifugal pump adopted by Messrs. Gwynne, and recommended by them where a large supply is to be raised from an underground bed of water within ready reach. The pipe or tube selected, has a powerful screw attached to it; this is turned round and screwed into the ground. If the tube is large in diameter, a windlass or horse-power may be required to sink it, and in such cases it may be necessary to leave the end open so as to reduce the friction and the consequent power necessary for sinking. *Fig.* 59 shows the tube sunk to a proper depth in the water-bearing strata. A series of holes or openings is left in the lower end of the tube, a powerful sucking pump is applied to the upper end of it, and the water comes up, bringing with it sand, clay, &c.; this after a time makes a cavity, as shown, which acts as a reservoir for the water, and the more such wells are worked the better they will become. This mode of sinking, especially through quicksand, or where large quantities of surface water have to be contended with, offers highly important advantages.

Fig. 59.

I shall not have a better opportunity than the present of saying a few words upon the construction of wells. In the remarks already made I have given some figures representing the cost of sinking and boring.

In the harder portions of the chalk and the new red sandstone, as well as in the oolites and older limestones, wells require simply

sinking and forming without lining, but in clays and marls, in free and broken strata, and when passing through thin partings between rocks, they must be steined.

The character of the lining or steining, and the method of executing it, will depend upon the depth of the wells and the precise nature of the strata through which they are sunk. In some cases the lining will consist of bricks, laid flat, without either cement or mortar. In others it will consist partly of courses of bricks laid dry and partly of courses laid in cement, the distance between the cemented rings varying from 5 to 12 feet according to circumstances. Under conditions of special difficulty the bricks should be laid wholly in cement. In cases where quicksands are met with, or where it is intended to shut out top water, iron cylinders are resorted to as the lining. The exclusion of surface waters is sometimes effected by laying the brick steining in cement, and concreting or puddling between the bricks and the soil, and this may be quite sufficient in the majority of cases; but if the water which it is intended to exclude is of a polluting character—and the influx of a small quantity may be very prejudicial—it should be born in mind that there will always remain the possibility of its percolating through the soil outside the concrete or puddling, and rising up from the bottom to the level of the water in the well. In fact, it is only where there are layers of impervious rock or clay, down to which the puddle or concrete can descend, and with which a perfect junction may be effected, that outer waters can be excluded from wells with certainty. With increasing experience concrete will find greater favor with well sinkers. For the steining of ordinary wells of small diameter, $4\frac{1}{2}$-inch work, with the bricks meeting end to end, is amply sufficient. Nine-inch work, with or without cement, is more appropriate when the ground is treacherous and the diameter of the well greater. The bricks are sometimes laid in two rings, and sometimes edgeways, with the ends meeting, in the face of the work. In all cases radiated bricks should be used, and now that this form of brick is made with facility there is no reason why they should not be generally adopted.

The old method of executing steining by building on curbs of wood shod with iron, and allowing both curb and superstructure to sink down together, is not often now resorted to.

In considering, even cursorily, the construction of wells, the value of horizontal wells or adits—sometimes called galleries—as a means of storage cannot be omitted. In certain forma-

tions, where a large quantity of water has to be raised from a single well in a given time, they are invaluable. At the well at Reid's Brewery, in Liquorpond Street, in which galleries were driven in the chalk at a depth of 200 feet from the surface, and 64 feet into the chalk, the yield is stated to be 192 gallons per minute, or 101,178,000 gallons per annum. Water rises in the well to a height of 121 feet from the surface. The height of the surface is 70 feet above sea level, and the water therefore stands at 51 feet below the same datum. At Bishops Stortford, in a well of which the galleries were formed 154 feet below the surface and 38 feet deep in the chalk, the yield has been 10,000 gallons a minute, or 5,256,000,000 gallons annually. Only 25 gallons a minute came from the shaft itself, the remainder being supplied by the galleries.

Upon the subject of galleries or horizontal wells, the Engineer is referred to a very interesting publication upon horizontal wells, by Mr. Lucas, of the Geological Survey of England.

I have already made some general remarks upon *rain and surface waters*, and I will now endeavour to show under the heads of (first), water *from roofs and other impermeable surfaces*, and (second), water *from cultivated surfaces and from the under-drains of cultivated lands*, that they constitute in very many cases an available source of supply which the Engineer should not omit from consideration

Failing sources of an unexceptional kind, one or other of these waters will furnish a supply to which no reasonable objection can be raised, assuming that it is properly collected, preserved, and filtered.

(2) *Rain Water from Roofs and Impervious Surfaces.* The collection of water from clean roofs can hardly be over-valued if, as declared by Dr. Angus Smith, and satisfactorily proved in my own case, the rainfall can positively be preserved free of organic impurities, and raised to the highest standard of quality by careful collection and judicious domestic filtration. (See Section XXXV.)

There are many dwellings—I mean public institutions and mansions—in this country where the extent of roofing exceeds in superficial area half an acre, or 80 poles (660 × 33 feet), and very many more—mansions, for instance—where it exceeds a quarter of an acre, or 40 poles. An ordinary dwelling-house will cover 10 poles, and a rural labourer's cottage $2\frac{1}{2}$ poles.

An inch of rain falling on these surfaces will yield respectively 11,311 gallons, $5{,}655\frac{1}{3}$ gallons, $1{,}413\frac{3}{4}$ gallons, and $353\frac{1}{2}$ gallons. On the western side of the country the *minimum* annual rainfall reaches 25 inches; on the eastern 15 inches. If the

whole of these minimum quantities be collected they would amount to (1) 282,775 gallons, (2) 141,387 gallons, (3) 35,347 gallons, and (4) 8,837 gallons respectively on the west; and on the east to (1) 169,665 gallons, (2) 84,832 gallons, (3) 21,208 gallons, and (4) 5,302 gallons. Taking the domestic supply, per person, per diem, at 15 gallons, it will be seen that the quantity thus to be secured would be sufficient in the west for 50 persons, 25 persons, six persons, and one-and-a-half persons, and in the east for 30 persons, 15 persons, four persons, and one person all the year round, and, of course, to three times as many if, instead of 15 gallons a head, five gallons would suffice, which in times of drought it would probably do.

To secure the whole of the water thus placed at command it would be necessary, as already stated, to have the means of collecting and storing a certain proportion, say one-third or less, according to local meteorological conditions. (For tanks see Section LXVII.)

Where the quantity of water required is in excess of that which roofs will afford, it will be necessary to add an extent of surface, which may be prepared by covering the ground with concrete or other impervious material to throw off the required addition. A few poles of ground with a regular slope will frequently suffice for this purpose.

(3) *Water from the Surfaces and from the Under-drains of Cultivated Lands.* The water from cultivated surfaces, in which is included that which is contributed to our rivers by tributary streams, and which may have been rendered impure by the organic matter washed off such surfaces, is generally inferior in quality to that to be obtained from roofs and prepared surfaces. Nor is the water obtained from the surface of cultivated lands so good in quality as that placed at command by the under-drains of such lands. The quantity available in a year from the under-drains of clay lands will probably amount to one-third of the winter's rainfall, but the minimum discharge, upon which alone dependence can be placed, may be as little as one inch, or 22,622 gallons per acre. With this reduced supply, if supported by proper storage arrangements, two-and-a-half acres of land will suffice for the supply of a dwelling, containing ten persons, with 15 gallons per head per diem for a whole year.

Water from cultivated surfaces may, however, be made serviceable for use, where other means of supply fail, by simple filtration through natural soil. Thus it may become very far superior to the water now consumed by the majority of households in rural districts. The

preparation of the filter beds of natural soil through which to run these waters is simple enough. A plot of land by the side of a stream may for convenience be selected for the purpose. It must be under-drained as deeply as possible, and the water being diverted from the stream should be evenly distributed over its surface, and if the distribution be regulated by furrows, it may be effected with precision.

The water of under-drainage, if found to contain ingredients of an objectionable character after its passage through the ground to the under-drains, can be rendered perfectly unobjectionable by a second filtration through a plot of prepared soil, as pointed out in the case of surface waters.

I am prepared to hear objections to the use of any water that may have been once impure; but when we are taught by chemists to believe that the extraordinary purifying powers of aërated soil will render innocuous large quantities of sewage in which exists organic nitrogen in considerable amount, we must be satisfied that by a second passage through natural soil, the water of under-drainage may be positively freed from any putrescible ingredients it may have contained. The advantage of filtration through soil has been shown at Merthyr Tydfil, where the effluent water of the under-drains of the land to which sewage was applied, was found by the analyses of the Rivers Pollution Commission, to contain, on an average, not more than ·032 parts of organic nitrogen per 100,000 parts of water.

LXV.—Of different Motive Powers to raise Water from Wells and Underground Tanks. Having referred to the several sources from whence a supply of water may be gained for the dwelling, we have now to consider by what means the quantity required for use may be most economically delivered to it—whether, failing gravitation, the power necessary for the purpose shall be exerted by hand, horse, wind, water, or steam.

The choice will necessarily depend upon the depth from which the water has to be lifted, the height to which it has to be raised, the rate at which it must be delivered, and the total quantity required for use. The power afforded by steam may be said to be always at command and to be unlimited; with water or wind the power afforded will be dependent upon local circumstances.

To arrive at the value of manual and animal power, Telford adopted the rule that "the work done by an animal is greater when the velocity with which it moves is one-third of the greatest velocity with which it can move when not impeded, and the force then exerted is four-ninths of the utmost force the animal can exert

at a dead pull." He considered that a man of ordinary strength could exert a force of 15 lbs. at a crane handle moving at the rate of 220 feet per minute per day of eight hours, while an ordinary horse when drawing at the same speed—220 feet per minute—would be able to exert a steady pull of 150 lbs for eight hours per day—220 × 150 = 33,000 foot pounds per minute. At this rate a horse is equal to ten men.

I give this here, as the power to raise 33,000 lbs. to a height of one foot per minute is that which is now generally taken, as you well know, as the datum power of a horse in calculations of the service of different motors.

Boulton and Watt arrived at the same result in a different way, though they considered that the power of a horse was only $5\frac{1}{2}$ times that of a man.

The usual calculation is that an average horse has seven times the power of an average man—a proportion which will be found to agree with the figures given in the following useful table of *Power required to raise Water from Deep Wells*, which I extract from Molesworth's book of *Engineering Formulæ*:—

Diameter of pump barrel.	Description of pump.	Quantity of water raised per hour.	Maximum depth from which this quantity can be raised by each unit of power.			
			One man turning a crank.	One donkey working a gin.	One horse (animal) working a gin	One horse-power steam engine.
Inches.	Double-action lift and force pump.	Gallons.	Feet.	Feet.	Feet.	Feet.
2		225	80	160	560	880
$2\frac{1}{2}$		360	50	100	350	550
3		520	35	70	245	385
$3\frac{1}{2}$		700	25	50	175	275
4		900	20	40	140	220

A gallon of water weighs 10 lbs., and if we apply the data I have given, it will be seen that the maximum number of gallons which can be raised by an average horse one foot high per hour reaches 198,000 gallons, and by an average man 28,286 gallons.

In practice however, a considerable allowance must be made for the loss of power resulting from friction, and from the inappropriate, or defective nature of the machinery by which the power is utilized. It may be well, therefore, to explain the different mechanical arrangements which are usually adopted in the raising of water, and before doing so give you here some deductions made from certain details which I have

obtained from several of our principal pump-makers—Messrs. Gwynne, Essex St.; Messrs. Owens & Co.; Mr. Mason, Ipswich; Messrs. Tangye; and Messrs. Wilson & Co.—and which I have reduced to the form of the following table, showing when hand, horse, or steam power (or its equivalent in wind or water) can be most economically adopted.

TABLE showing the description of pump to be adopted, the character of power required, and the time taken to raise different quantities of water from various depths below, to a height of 60 feet above, the surface of the ground for the supply of dwellings:—

Depth of water from surface of ground.	Total quantity of water required to be raised daily.	Description of pump to be used. Character.	Number of barrels.	Length of stroke.	Character of power to be employed.	Quantity raised in one hour.	Time taken to raise the total quantity.
Ft.	Galls.			Inches.		Galls.	Hrs
25	250	2½″ lift and force pump.	1	6 to 9	One man or strong boy.	170	1½
	1,000	3″ ditto.	2	7 to 9	Two men or donkey.	340	3
	5,000	4″ ditto.	3	9 to 10	One horse.	1,000	5
	25,000	6″ ditto.	3	12 to 18	3 H.P. engine.	5,000	5
	50,000	7½″ ditto.	3	18 to 21	4 H.P. engine.	10,000	5
60	250	2½″ ditto.	1	6 to 9	One man or strong boy.	125	2
	1,000	3″ ditto.	2	9	Donkey or pony.	500	2
	5,000	4″ ditto.	3	9 to 12	Two horses. / 2 H.P. engine.	1,000 / 1,500	5 / 3½
	25,000	6″ ditto.	3	12 to 18	4 H.P. engine.	5,000	5
	50,000	7½″ ditto.	3	18 to 21	6 H.P. engine.	10,000	5
100	250	2½″ ditto.	1	7	One man.	100	2½
	1,000	3″ ditto.	3	9	One horse.	400	2½
	5,000	4″ ditto.	3	9 or 10	Two horses. / 2 H.P. engine.	1,000 / 1,500	5 / 3½
	25,000	6″ ditto.	3	12 to 18	6 H.P. engine.	5,000	5
	50,000	9″ ditto.	3	18	12 H.P. engine.	10,000	5
200	1,000	3″ ditto.	3	9	Two horses. / 2 H.P. engine.	400 / 800	2½ / 1¼
	5,000	4″ ditto.	3	9	2 H.P. engine.	1,000	5
	25,000	6″ ditto.	3	15 to 18	8 H.P. engine.	5,000	5
	50,000	9″ ditto.	3	18	12 H.P. engine.	10,000	5
300	1,000	3″ ditto.	3	12	2 H.P. engine.	700	1½
	5,000	4″ ditto.	3	12	4 H.P. engine.	1,500	3½
	25,000	6″ ditto.	3	15 to 18	8 H.P. engine.	4,000	6¼
	50,000	9″ ditto.	3	18	14 H.P. engine.	7,200	7

In these figures it has been assumed that the water required has to be lifted to a height of 60 feet above the surface in each case. Where, in addition to this height, the depth of the water beneath the surface does not exceed 25 feet, it would appear from the foregoing table that 170 gallons an hour will represent the extent of a

man's power, while two men may raise double this quantity, and a horse 1,000 gallons.

With a depth of 50 or 60 feet beneath the surface, a man may raise the water at the rate of about 125 gallons an hour, and a donkey will raise as much as 500 gallons, a superior power having to be resorted to as the rate of delivery is increased.

With the water at a depth of 100 feet from the surface, a man may still be economically employed if the rate of delivery need not exceed 100 gallons an hour, and a horse will be available for quantities between this and 400 or 500 gallons. Beyond this latter rate, however, it will be desirable to resort to steam.

With water at a depth of 200 feet below the surface, both manual and animal power will give way to mechanical power as the more economical.

(1) *Manual Power.* Leaving the pump itself to be dealt with presently, there is little to be said upon the arrangements by which manual power can be economically utilised. Where the depth from which the water is lifted does not exceed 25 feet, and the quantity of water used daily does not exceed 500 gallons, the common atmospheric, *i.e.*, the suction or lift-pump, with its levered handle, is the best and cheapest.

Where the quantity to be raised is comparatively large and the depth considerable, the levered handle must give way to a framed arrangement of gearing which can be worked by wheel and pinion, and which readily allows of the employment of either one or two

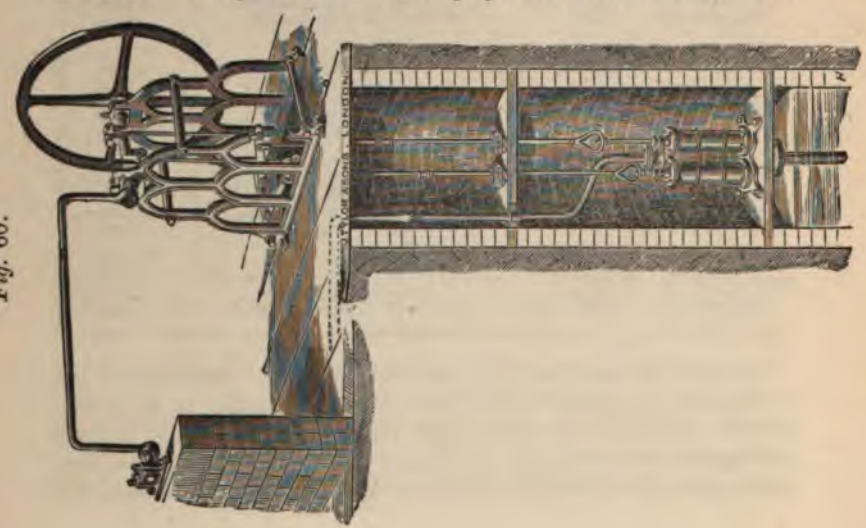


Fig. 60.

men as required. Examples of the forms in which this arrangement may be adapted to the employment of a number of men, as may be done in workhouses, prisons, &c., are given in *Figs.* 60 and 61.

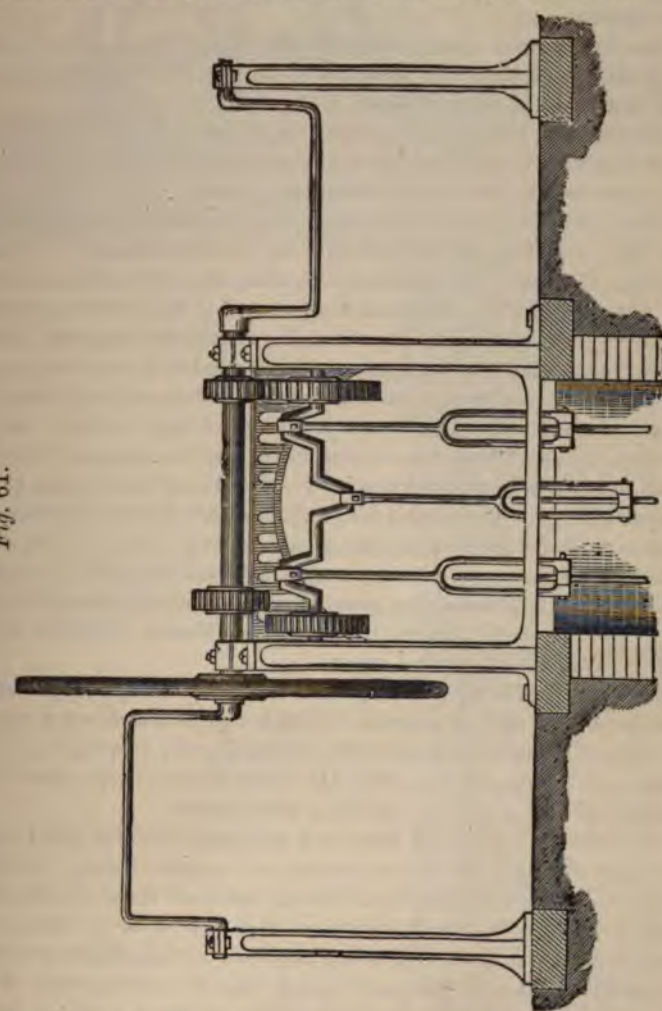


Fig. 61.

(2) *Horse Power.* The gearing necessary for the application of animal (horse) power to the raising of water by pumps, requires but few words. The gearing itself and its connection with the pumps is shown by *Fig.* 62, and by means of different sized cog-wheels the

speed of the pumps may be regulated, and the slower pace of one animal compared with another overcome. The gearing may be placed either directly over the well or by the side of it, as in the illustration.

The horse-power arrangement should, where practicable, be from 25 to 30 feet in diameter, though a horse will walk without discomfort in a circle of 18 or 20 feet.

Drawing V. shows the application of horse (animal) power to a set of treble 3½-inch pumps raising water from a well 120 feet deep into a cistern placed 20 feet above the ground, and holding 2,000 gallons. The work which this drawing exhibits was carried out for the Earl Verulam, at Gorhambury in Hertfordshire, by Messrs. Owens. Two donkeys, yoked side by side, raise 500 gallons an hour.

(3) *Wind Power.* There is every reason to believe that in raising underground water from a considerable depth, the neglected power of wind will come into use again, supplemented as it may be by steam or horse-power when the wind fails.* Wind was at one time very commonly utilized in this country. It gave way to water, as the more certain, and water in its turn gave way to steam, as the most manageable of all motive powers. Now that coal is becoming expensive, and water is in demand for many purposes for which steam has been used, attention is again being paid to wind, and the ingenuity of the Engineer is sought to furnish the most economical form of wind engine. Excellent engines which need not be described here are already made by Messrs. Owens & Co.; Messrs. Gwynne & Co.; Messrs. Warner & Co., and others.

Figs. 63 and 64, representing an arrangement adopted by Messrs. Warner & Co., will be suggestive of the way in which wind may be utilised, either in conjunction with animal (horse) power (*Fig.* 63) or with a small steam engine, (*Fig.* 64) either the one or the other being worked instead of wind as occasion necessitates.

The extreme number of days in a year on which the wind might not have sufficient power to perform the required duty, has been stated to be less than 100 days, but any estimate to be of value must depend so much on local influences, that this must be taken with reservation. An absence of wind, however, would seldom last more than a fortnight at a time, and seeing that the service tank of any establishment—and indeed of any village—may be made to hold a quantity sufficient for a certain number of days or weeks, and that the wind when at work would do duty during the night as well as

* See also *Village Sanitary Economy—Journal of the Royal Agricultural Society of England*, by the Author.

Fig. 62.

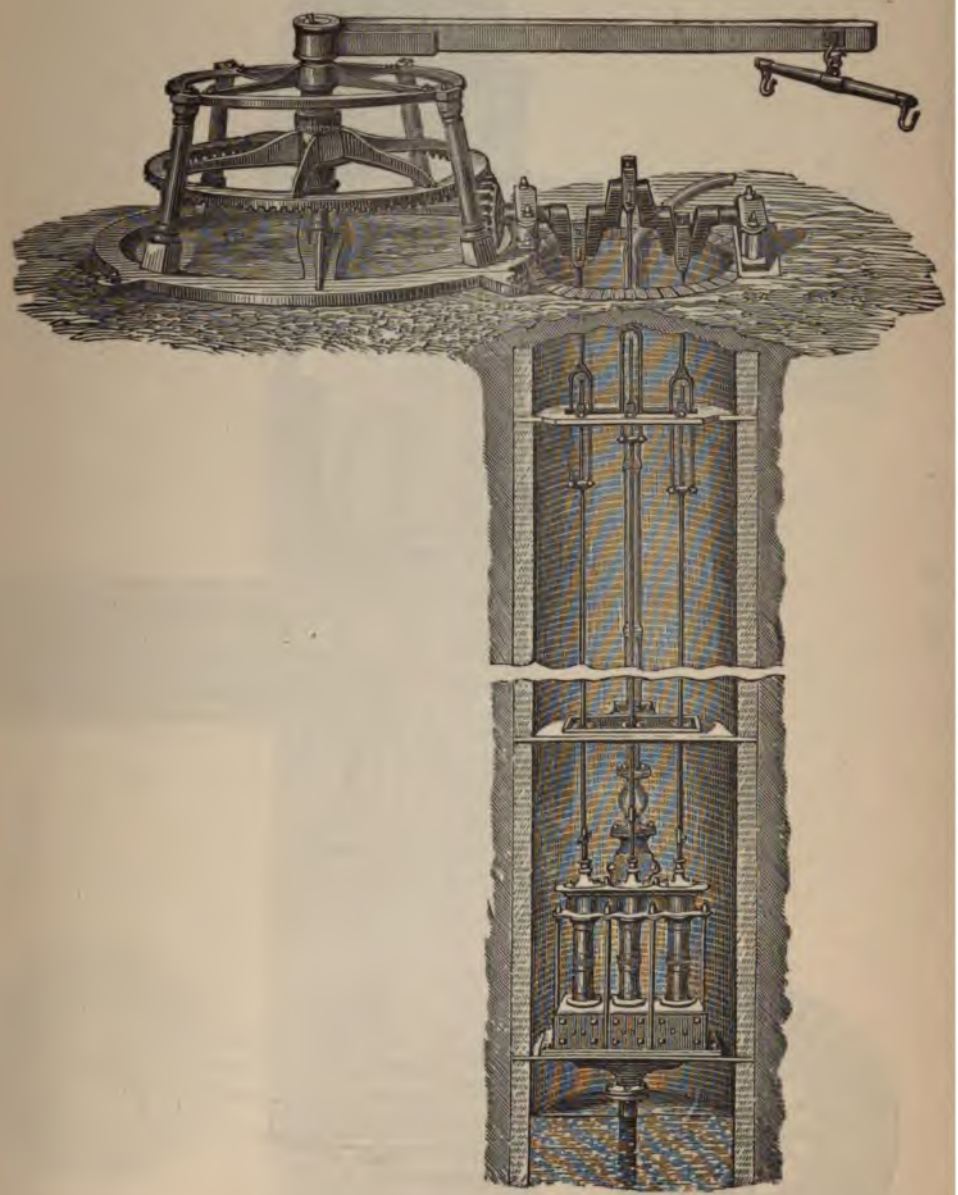


Fig. 63.

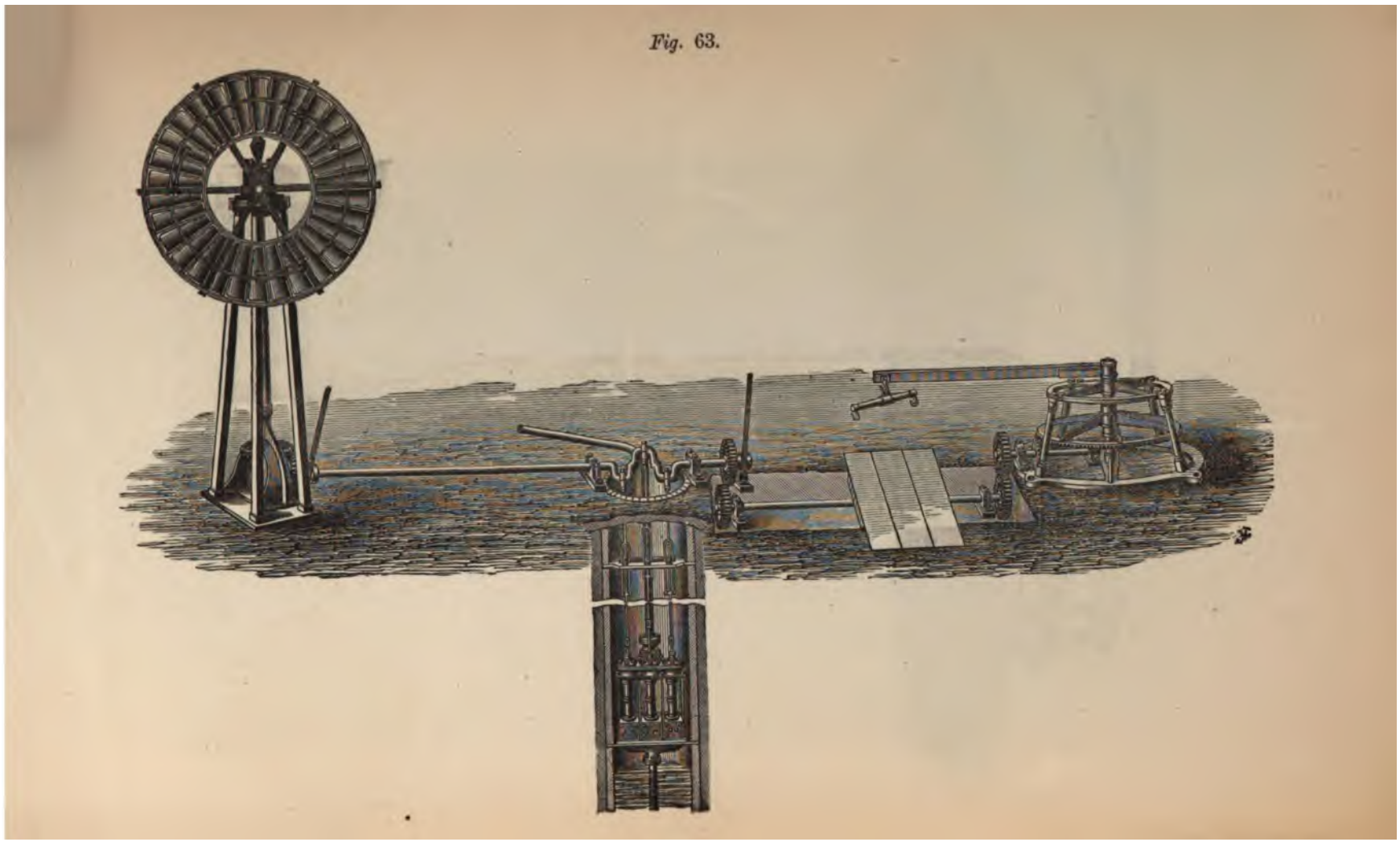


Fig. 64.

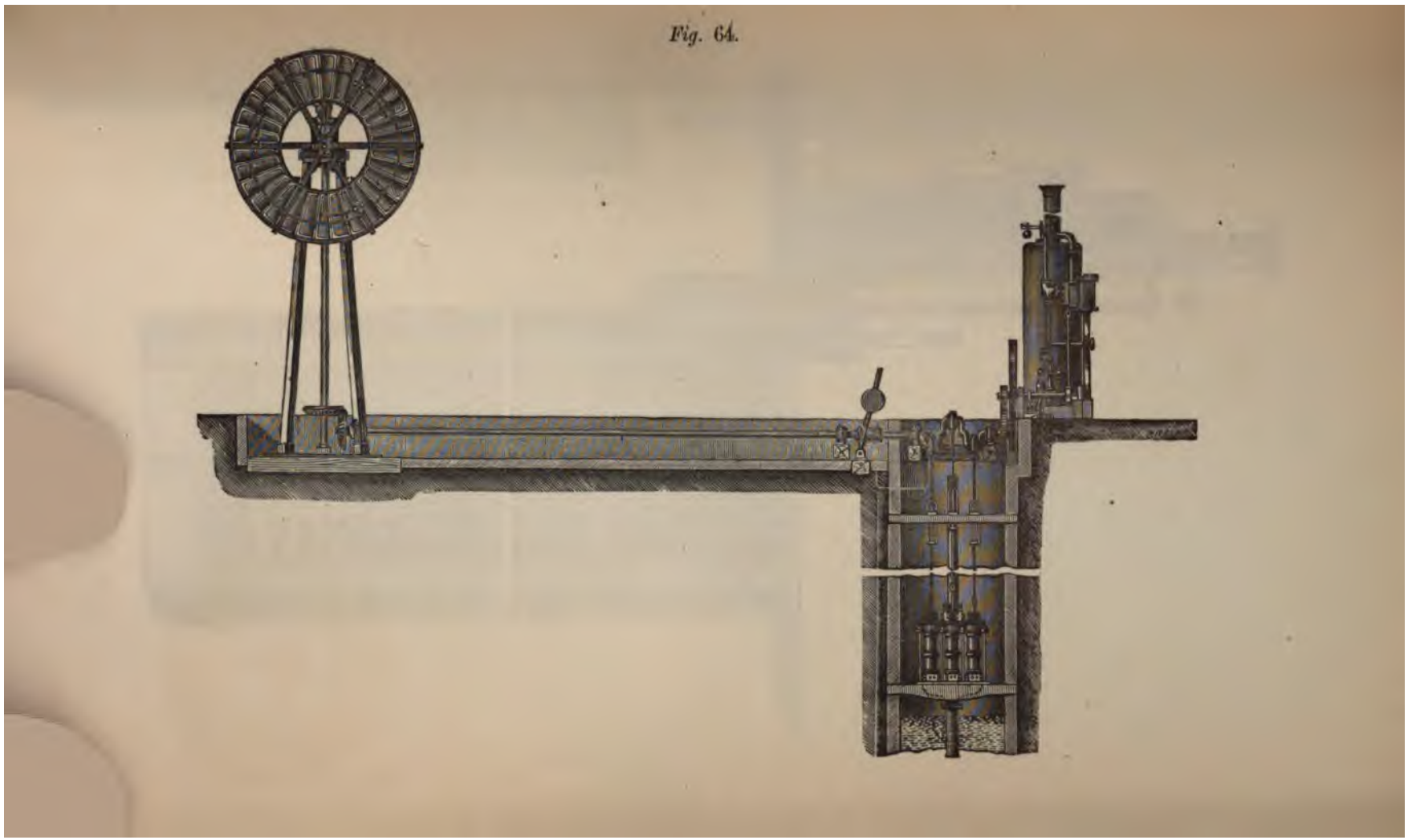
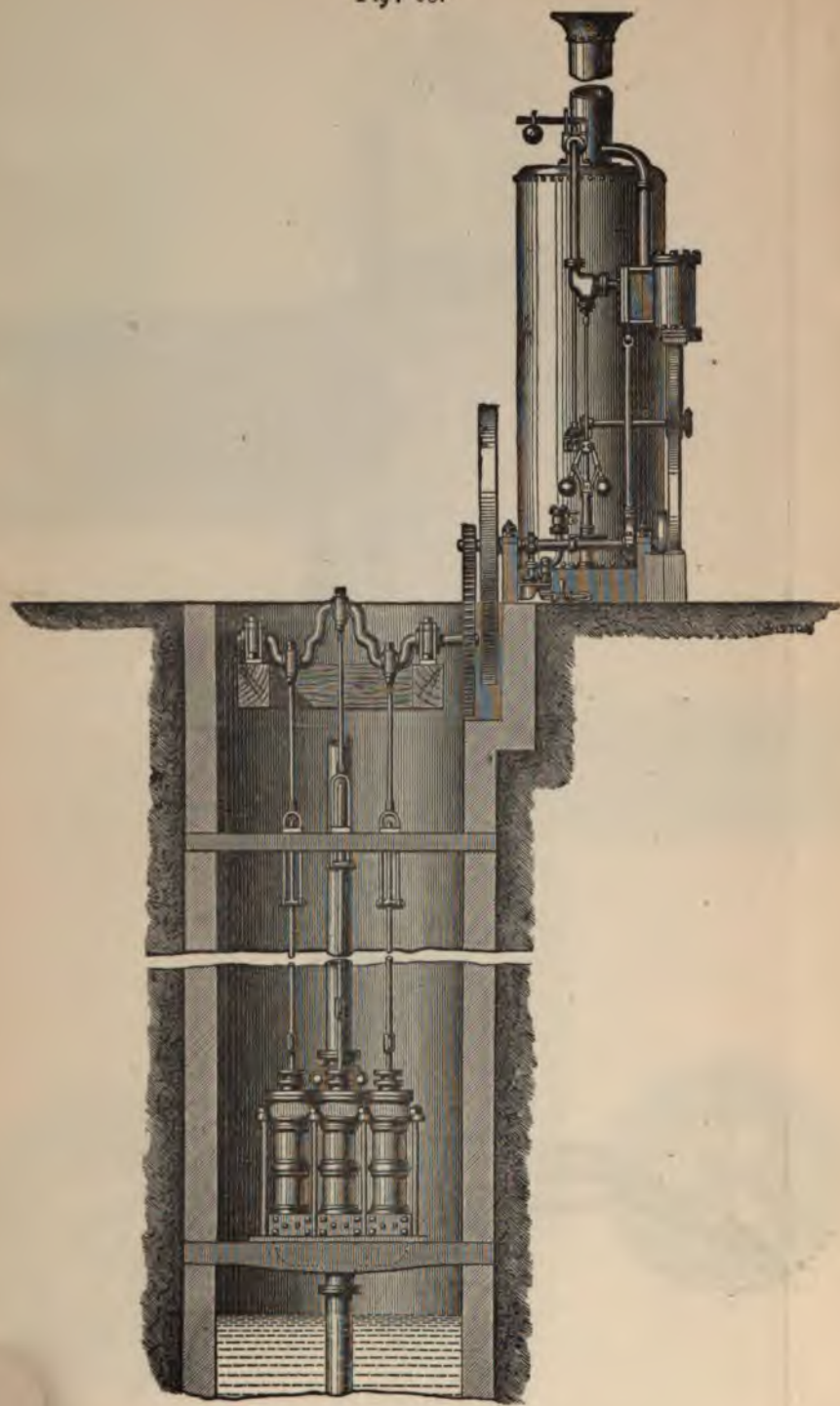


Fig. 65.



the day, it may be fairly assumed that recourse to supplemental power would not be frequent. When the wind fails, a good strong horse, or a steam engine working a few hours occasionally, will suffice to make up the deficiency.

(4) *Water Power.* The readiest means that can be used for raising water from running streams or springs is water itself. Where it exists in quality sufficiently pure for domestic use, and in quantity sufficient to be used as a power at the same time, the hydraulic ram will be found to be the cheapest and best motor, though the wheel, the turbine, and hydraulic engines working with compound arrangements, have each superior advantages where such special conditions do not exist.

The Ram. Where the quantity of water is small and its quality perfectly pure, and where the elevation to which the water has to be raised is not too great, the hydraulic ram commends itself as the most economical of all water lifting machines. An ordinary ram with a fall, for instance, of eight feet, and with a flow of water to it of 38 gallons per minute will raise 4,000 gallons per diem, from 40 to 50 ft. in height to a distance of half-a-mile.

The principle of the ram is different to that of any other hydraulic machine, as by concentrating into a small quantity the force accumulated by the motion of a larger body the small quantity is raised to the required height. The fall to the ram should in no case exceed 20 feet, or repair will be frequently needed. As the hydraulic ram differs in its principle of action from all other means of raising water, so its useful effect varies according to a different law. For instance, when the height to which it is desired to lift the water amounts to eight times the fall which works it, the useful effect will be 66 per cent., but when the elevation is ten times the fall, the useful effect will be reduced to 50 per cent., while at twenty times the fall, the useful effect will be only 18 per cent.

A section and elevation of the hydraulic ram is given on *Figs.* 5 and 6, *Drawing* VI.

A ram very suitable in cases of isolated dwellings has been introduced into this country from America, and is known as the Douglas Ram. Its action will be readily understood by the following reference to the case of Lea Hall—a farm house in Cheshire. The water supply to this place is lifted from a stream which has been dammed up so as to give a head or fall of 8 ft. 6 ins. From this stream a volume of water equal to about 25 gallons per minute flows into the ram. Of this quantity about one-eighth is delivered to the farm house and buildings, which lie at a height of 50 feet above, and

a distance of about 100 yards from the ram. This ram is stated to be applicable where no more than 18 inches of fall can be had, though the greater the fall, the more effective will be the result. It is also stated that a fall of 10 feet is sufficient to raise water to any elevation under 150 feet, and that in conveying it to a distance of 50 or 60 yards it may be calculated that about one-seventh of the water can be raised and discharged at an elevation above the ram five times the height of the fall working it.

Messrs. Gwynne recommend the hydraulic engine shown on *Fig.* 4, *Drawing* VI., working an ordinary reciprocating double-acting pump, instead of the double-acting ram, when it is desired to pump up clean water by the use of foul or dirty water. They say "there are rams which are made to do this particular purpose, but the duty which they give out is so very little, in some cases not more than 10 per cent., that we have designed this hydraulic engine to take their place—the duty of which we have found after very careful experiments to be 60 per cent. We should not advise this form of machine for low falls, nor for extreme high falls, it being applicable to moderate falls. The machine requires very little looking after, in fact no more than the ram, and will work continuously as long as there is water to supply it."

The Wheel. The principle of the water wheel is so well understood that I propose referring to it only in brief terms. In doing so, however, I do not wish to underrate its importance in the water supply of the dwelling, for there are many institutions and country mansions in close proximity to running streams whose waters may, by means of its use, be usefully and inexpensively employed.

During recent years the water wheel has undergone many improvements, and wood has greatly given way in its construction to iron and other metal. The wheel known as the overshot wheel gives a greater power than any other form where the fall is comparatively great, and the quantity of water available to work it is small. Where, as will be the case in the majority of instances, the river or stream at command has but a slight inclination, and where therefore the overshot wheel could not be adopted, the undershot wheel will be found serviceable. Between the two extremes the breast wheel may be turned to better account.

Comparing the undershot wheel with the overshot, the relative efficiency of the latter may be taken to be about double that of the former, while the breast wheel will yield a result rather greater than the mean of the two.

The Turbine. The turbine has of late years undergone many improvements and M. Fourneyron has done much towards its present

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perfection. M. Girard, of Paris, who unfortunately was killed at the recent siege of that city, also spent much time in the improvement of the turbine, and the machines which have been constructed upon his designs are amongst the best we have. No machine, however, requires more absolute perfection in its proportions to give a good result, and many that are sold are very far from being fully effective owing to imperfect design or construction. *Fig.* 7 on *Drawing* VI. shows a turbine in section.

On a large scale very high results have been obtained, but for small applications 70 per cent. only of the power expended may be considered the limit of perfection, while from this there must be a further deduction due to the pump and gearing, which will reduce the product to 50 per cent.

Messrs. Gwynne, of Essex St., have designed several machines in which they connect the turbine with different pumps. *Drawing* VI. *Fig.* 1, shows the latest combination of the turbine and centrifugal pump for raising water a moderate height, of, say 40 feet. It is suitable for a low fall and works with very little attention. *Fig.* 2 shows a turbine also suitable for a low fall, but working a high lift pump to deliver at an elevation of 100 feet or more. This, Messrs. Gwynne say, is the simplest arrangement possible, as there is no gearing or straps of any sort. Another form which those experienced makers recommend is that shown by *Fig.* 3, and which consists of a turbine suitable for a considerable fall working a pair of force pumps.

(5) *Steam Power.* Steam, unlike wind or water used as motive power, possesses the advantage of being capable of application to any extent at any time. It has the disadvantage, however, of not only involving a comparatively heavy first outlay, but of requiring the provision of skilled attendance, and of necessitating a constant expenditure in fuel, &c., though this latter item may in many cases be reduced by the provision of storage reservoirs or tanks, when the engine need only then be used two or three times a week. In all cases where the power required is great, steam will form the most suitable motor, and many excellent machines are now made which may be used either in combination with the ordinary lift and force pump, or with the more modern centrifugal pump.

I do not here propose to go into the constructive principles of these engines.

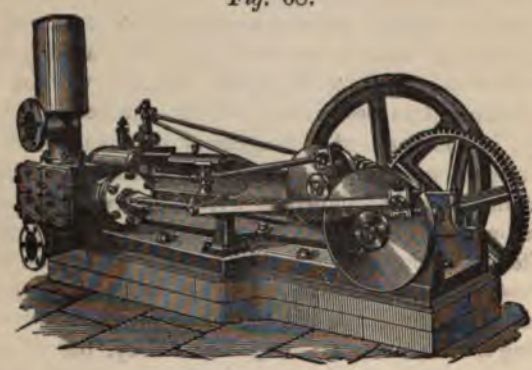
In many large establishments in rural districts, steam power may be required for other purposes than water supply. In such cases the familiar portable engine may be very advantageously adopted. It can be readily attached to, or detached from, the pumping machinery, and used for one purpose when not wanted for another.

Where a fixed steam engine is preferred it is not an uncommon practice to adopt an arrangement similar to that shown, for instance, by *Fig.* 65; which represents one of Messrs. Warner's engines.

Figs. 66 and 67 show the Combined Centrifugal Pumping Engine of Messrs. Gwynne. *Fig.* 66 is a perspective view, showing a vertical suction to the pump, and *Fig.* 67 is an end elevation of the pumping engine, with a horizontal suction to the pumps. A is the case of the pump; B the suction pipe; C the discharge pipe; D the steam cylinder driving the pump direct, without the intervention of any gearing whatever; E is the steam pipe connected with the steam boiler; and F is the exhaust pipe from the engine. In these forms they are best suited for low lifts.

Fig. 68 represents a combined horizontal high pressure expansive steam engine and double action pump, manufactured by Messrs. Tangye.

Fig. 68.



LXVI.—Of Pumps. The pumps most suitable for the raising of water for the supply of dwellings from wells and tanks may be classified as follows:—(1), the atmospheric or common suction or lift pump; (2), the lift and force pump in its various forms; and (3), the centrifugal pump.

In practice it is found that a depth of 28 feet is the limit from which water can be favourably drawn by the first class of pumps.

Fig. 69 shows, partly in elevation and partly in section, one of Warner's ordinary suction hand pumps.

Wherever the limit of 28 feet is exceeded, or where it is necessary to raise the water to any height above the surface of the ground, upward forcing power must be resorted to. In deep wells an arrangement is often adopted by which the water is forced up a rising main by the down stroke of the piston; but for ordinary

Fig. 66.

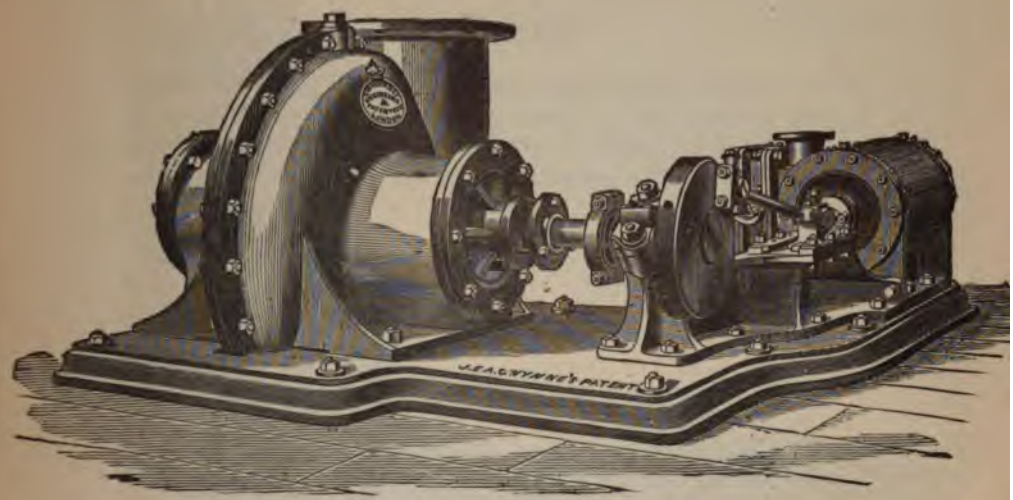

J.E.A.C. WYNNE'S PATENT

Fig. 67.

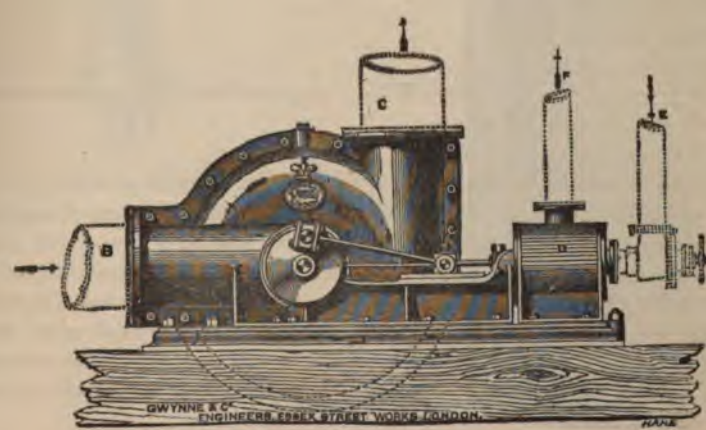
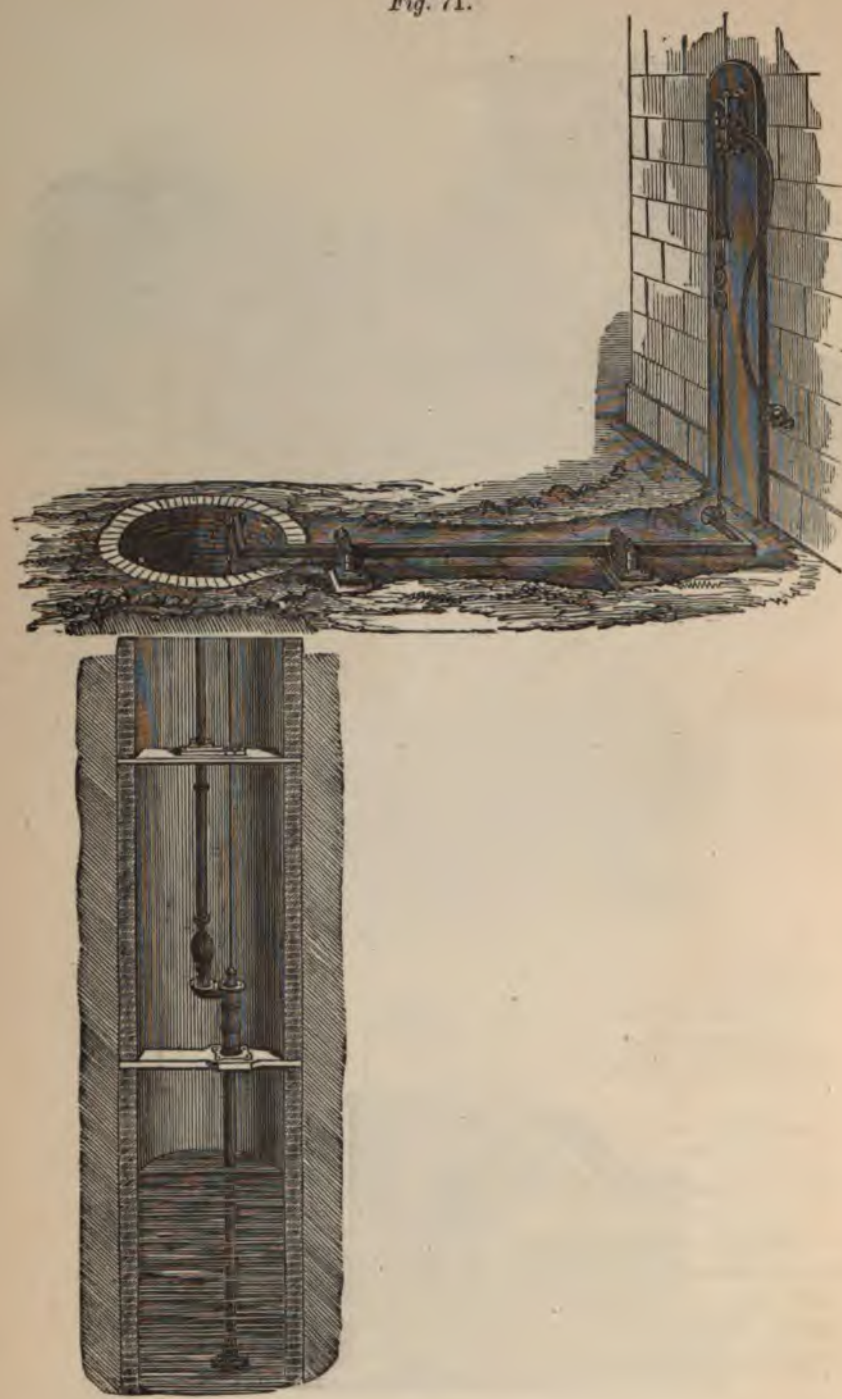

C
GWYNNE & Cº
ENGINEERS, ESSEX STREET WORKS, LONDON.

Fig. 71.



purposes the suction power of the lift pump is combined as far as possible with the forcing power which may be gained by the up-stroke of the piston or bucket. These pumps are known as lift and force pumps. A pump of this character is shown by *Fig.* 70.

Fig. 69.

Fig. 70.

Fig. 71 shows how the lift and force pump of a size suitable for hand power may be fixed and worked. When used in wells the barrel of the pump will generally be fixed near the surface of the water, the depth between the barrel and the water in the well representing the suction action of the pump, and that above, its forcing power.

All other barrel pumps are modifications of the lift and force pumps to some extent or other. They are arranged on a single or double acting principle by different arrangements of valves or pistons,

or by double or treble barrels. The arrangement of the latter will be observed in some of the illustrations which have been already given, and a front and side elevation of a pump with three barrels, or a three throw pump, as it is called, is shown by *Figs.* 73 and 74.

Fig. 73.

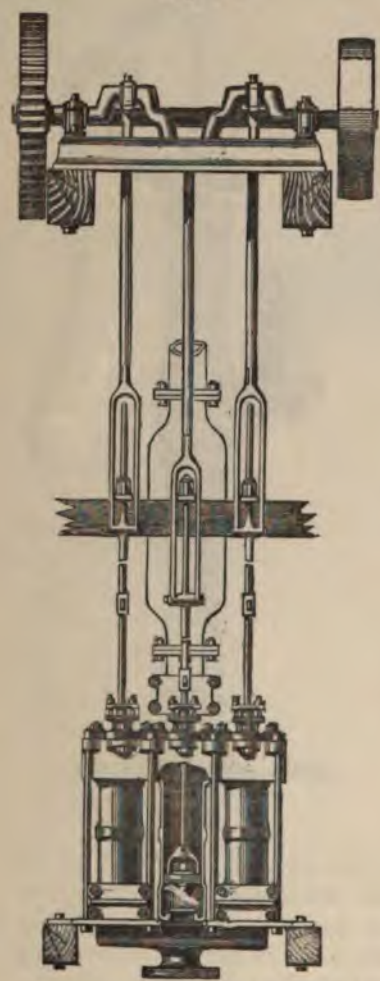


Fig. 74.

The different modifications give to pumps different names:—they are sometimes called bucket pumps, ram and plunger pumps, bucket and plunger pumps, and sometimes solid piston pumps.

A continuous stream is very effectually secured by pumps worked in sets of three, and in those known as plunger and bucket pumps, which act both in the up and down stroke.

In fixing force pumps in situations where the rising main is of any length, an air vessel should be provided, in order to relieve the pipe from strain and to insure a continuous discharge of water. (See *Figs.* 73 and 74.)

When hand power is employed the single barrelled pump worked by levered handle, or the doubled barrelled pump worked by frame and crank, may be adopted, but with horse or steam power as the motor, the treble barrelled pump is to be preferred.

In shallow wells the internal diameter of the suction and force pipe should never be less than two thirds of the internal diameter of the barrel of the pump, and in deep wells the suction and force pipe should each be of the same size as the barrel.

In all wells—especially in deep wells—it is desirable that the pump work should be fitted with great care and strength.

The centrifugal pump is now coming more and more into use. Its name explains its action; it is very compact, and is easily connected to the ordinary rotative steam engine by a driving belt. These pumps are not, however, applicable to very high lifts. The

Fig. 75.

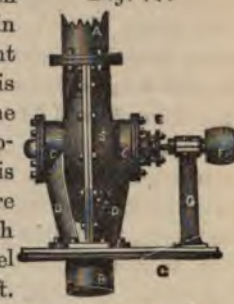
Fig. 76.

centrifugal pumps made by Messrs. Gwynne, are shown by *Figs.* 75, 76, and 77.

Fig. 75 is a perspective view, *Fig.* 76 is a side elevation, and *Fig.* 77 is an end elevation of the pump. In the last figure, S is the

body or case; C C the side cylinders or water passages communicating with the revolving wheel, or disc, and DD the suction pipes on each side of the case, which unite together on or below the bed plate G, in one pipe B. This is considered an important feature in the arrrangement, as the machine is rendered extremely compact. In one of the cylinder covers or ends, there is a bearing supporting the spindle on which the wheel is fixed; in the other cylinder or cover there is a gland and a stuffing box E, through which the shaft of the revolving wheel passes. Q is a standard supporting the shaft. F is the pully by which motion is communicated to the pump from any prime mover. A is the discharge pipe, which may be carried upwards to the required elevation. The suction pipe B may, if desired, be run any moderate length horizontally, and the pump may be placed 15 to 20 feet vertically above the water to be raised. A foot valve is placed at the bottom of the suction pipe.

Fig. 77.



The action of the pump may shortly be stated to be as follows:— The pump case and pipes being filled with water, the wheel or disc is caused to rotate, and by the centrifugal motion thus given to the water contained in the disc, it is driven out into the case or receiver of the pump. The partial vacuum thus formed in the disc is filled by the water forced up the suction pipe by the pressure of the atmosphere; in entering the disc centrifugal motion is communicated to the water by the revolving disc, and thus a continuous stream is received into and discharged from the pump. To prevent the water from rotating in the case, and to give it a direction upwards to the discharge pipe, a stop or plate is placed at the base of the discharge pipe, reaching to the joint between the piston and the case.

In addition to the foregoing there are the pumps known as chain pumps, consisting of an endless chain having buckets or dishes attached at short intervals. These pumps are, however, hardly suitable for the raising of water for domestic use in dwellings. They may be advantageously used where there is sand or other impeding matter in the water, and I here refer to them that I may be guilty of no omission. The same remark applies also to various other machines which are occasionally used for the raising of water in different conditions, some of them being of ancient origin, such as the old noria—which is not unlike the modern chain pump—or the screw or spiral pump, which may be used for special purposes.

LXVII.—Underground Tanks for the Storage of Water. The storage of water in reservoirs or underground tanks for the supply of private dwellings is an object requiring much care and attention in details. If it is determined to collect surface waters it will be necessary to have proper and ample storage room to meet any droughts that may occur. A provision for the consumption of 120 days may be taken as a safe one, even in the driest parts of England.

The cost of making underground tanks, which must be perfectly water-tight, so as not only to prevent the escape of that which is stored, but also to preserve the stored water from the influx of polluting "ground water," will vary extremely.

In certain situations where the subsoil is of such a character as to allow of the space which the tanks are to occupy being cut out of the ground in the precise shape and size the proposed tanks are to be made—and this can be done in the chalk, and the new red sandstone formations with remarkable exactitude—it has been found necessary only to face the surfaces of the excavation with a rendering of cement to make them water-tight, and then to cover them with a roof of brickwork springing from shoulders of concrete or resting on iron girders. These have been constructed under favorable circumstances at the low cost of from 30/- to 40/- per thousand gallons.

The increasing experience which we are now gaining in the use of concrete, facilitates the construction of tanks in soils not naturally so favorable as those which I have just referred to, at a cost much less than formerly, if proper care is taken in the selection and mixing of the ingredients, and in the washing out of any earthy matter. Portland cement is found to be better than the best lime, though concrete, consisting of one part of blue lias lime, and six parts of gravel and sand—or of the proportions which are favored in France, consisting of two parts of broken stone to one of mortar, the latter being composed of three parts of lime to five of sand,—with an inside rendering of Portland cement and sand in equal proportions, will form a tank of unexceptional character. The thickness of concrete will depend upon the soil in which the tank is constructed. If it be of a slipping character the thickness must be increased.

In some cases it will be found desirable, instead of "rendering" the inside with cement only, to line the concrete with $4\frac{1}{2}$-inch brickwork, laid in cement and well grouted with a coat of the same material between the brickwork and the concrete.

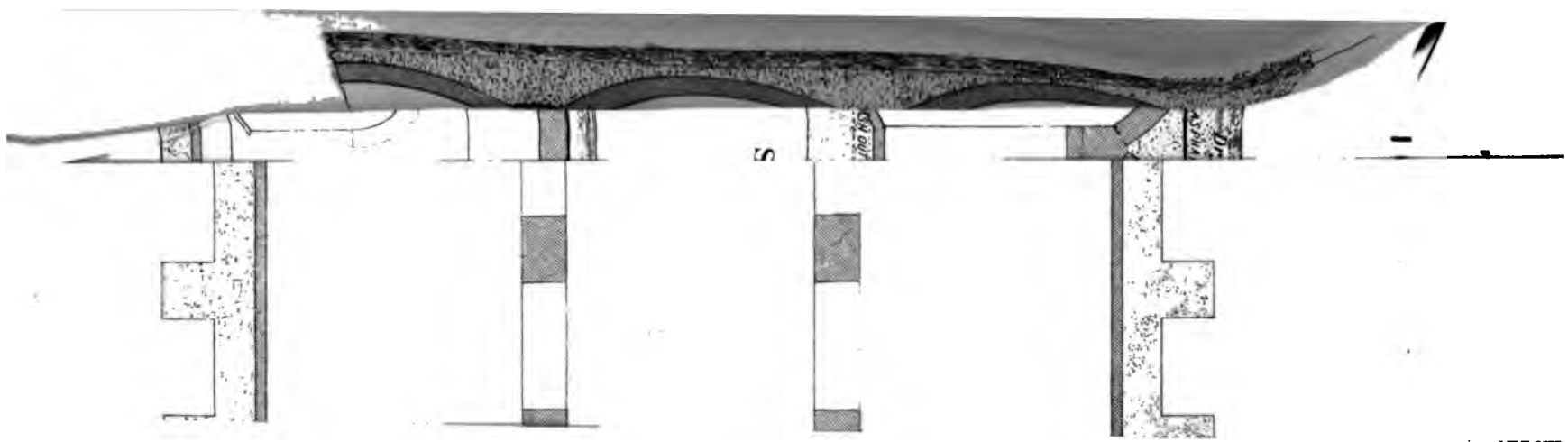
Where the tanks are of large dimensions, it will be necessary to support the roof with brick piers and buttresses, and construct the roofs of brick or concrete. (See *Drawing* VII.) The cost of these tanks will vary from £5 to £7 per 1,000 gallons. A tank 16 feet by $12\frac{1}{2}$ feet, and 8 feet deep, will hold more than sufficient to supply five persons with 15 gallons of water for 120 days, after allowing for evaporation; while a tank 16 feet square, and 12 feet deep will hold more than sufficient to supply 10 persons with 15 gallons for 120 days. In the one case the storage space will be 9,600 gallons, and in the other 19,200

Drawing VII. shows underground tanks suitable for dwellings and institutions of large character. It may be useful to remember that a rectangular space 16 feet by 10 feet holds 1,000 gallons in every foot of depth, and that a circular one $14\frac{1}{4}$ in diameter holds about the same number of gallons.

LXVIII.—Cisterns for Service of Water within the Dwelling. It is very unsatisfactory to be obliged to acknowledge that after obtaining water of a potable character from river, spring, or well, or after conserving it in tanks, it may lose its good qualities in the service-cistern into which it may be raised for household supply; but this is found to be the case in very many instances.

We have now been led by chemical analysis to look upon water as perhaps the most dangerous substance upon which human beings have to depend for life and health; and, at the same time, to admit that although we may obtain what is pure at its original source, and convey it in that condition to the dwelling, it may soon become defiled by the vapours, gases, and dust which pervade the atmosphere surrounding cisterns, or by the filthy condition of the cisterns themselves, or by the injurious character of the pipes by which the water is distributed for use. There is no doubt whatever that water is often most injuriously affected by foul cisterns and foul pipes. Nevertheless, there are but few exceptions in which isolated dwellings, beyond the reach of a public supply, can exist without cisterns, while there are many in which the disgusting practice of placing them in or near attics which are used as sleeping apartments prevails. In fact, in many of the largest houses in the country this condition of things will be found to be the case.

The best of all cisterns are those made of slate, enamelled inside, and those that are constructed of wrought iron, properly painted. Lead and zinc for the linings of cisterns are both decidedly



objectionable, though I believe that lead is often condemned when the evil complained of is due rather to the effect of certain *impure* waters upon lead than to any general effect of lead upon pure water. It appears to me exceedingly doubtful whether pure water really has the effect—so often imputed to it—of quickly oxidizing lead.

Where the whole of the water is raised to one service-cistern in the upper part of the dwelling, special arrangements should be made for the supply of water-closets and sculleries by separate subordinate cisterns, with ball-cock arrangements, so that the water required in either a water-closet or a scullery may be drawn without any *direct* communication with the main service-cistern. To remove defilements such as I have spoken of, a filter should be connected with all service-cisterns, through which the whole supply of the dwelling should pass as required for use, and every cistern should be closely covered. For remarks on regulating and waste-not appliances see Section LX., and for taps and cocks see Section LXXXVIII.

LXIX.—Domestic Filtration. In any arrangement for the supply of water to dwellings domestic filtration should be included, although the Rivers Pollution Commissioners have stated—and in their statement I concur—that, as it is usually practised, it is of little or no use. They state, however, that if domestic filtration is properly performed it is much more efficient in purifying water polluted by organic matters than that practised on a large scale by the water companies—usually through sand—and I would add that where the boiling of water is resorted to as a means of securing increased purification, the *deadened* character of the water resulting from boiling may be overcome by subsequent filtration through aërated material. My own experience has enabled me already to place before you some evidence (see Section XXXV.) that rain-water collected from clean surfaces is in itself so free from pollution that it requires filtration only to protect the consumer against the accidental defilements of smoke, soot, and those minor organic impurities which occasionally collect on roofs.

As already stated, all filtration in which the filtering material is placed constantly under water produces but an imperfect effect, and this is frequently the case in the filters now in use. To secure the best results the filtering material should be intermittently aërated. With this view I have contrived, and have adopted in combination, the two filters described in Section XXXV. The first being placed *under water*, gives out its effluent but little more than clarified.

The second—"the Self-Supplying Oxidising Filter" (*Fig.* 78)—being

Fig. 78.

A Filtering tank.

B Storage receptacle.

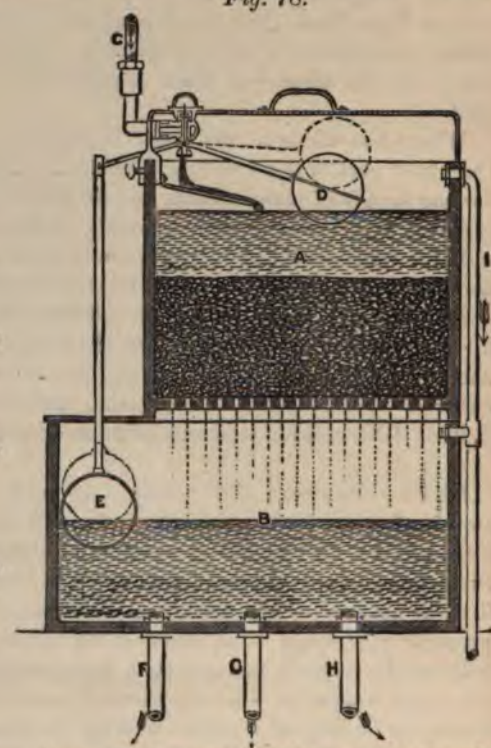
C Inlet from house cistern.

D Ball regulating influx to filter.

E Ball acting upon same valve as **D**.

F, G, & H Pipes to kitchen, pantry, &c.

I Overflow pipe.

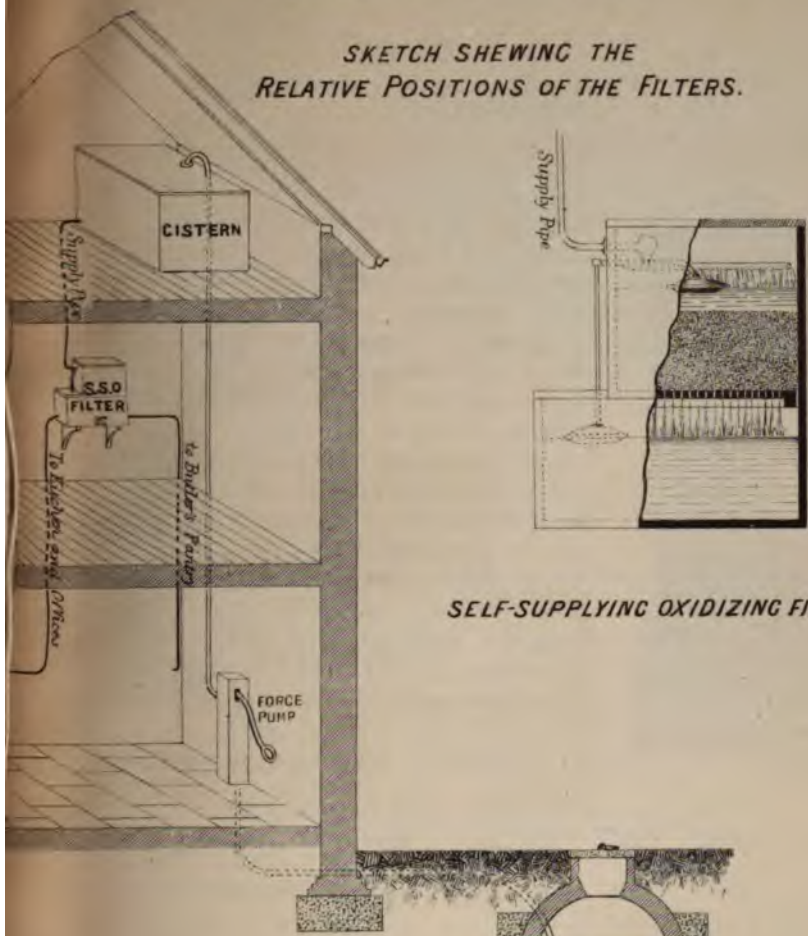


below the service-cistern, from which it receives fresh water already once filtered, as the consumption of the dwelling requires it, completes the purification by oxidation—see *Drawing* VIII, which is given only to show the relative position of the two filters. The self-supplying oxidizing filter may be made of any material and size to serve small as well as large establishments, and the filtering material itself may be of any kind and quantity. Its greatest recommendation is that the two compartments and the filtering material itself may be readily washed out by letting the water run through them. These filters may be used for small village supplies with good effect.

Out of the many filters now manufactured and sold I have selected, without giving preference to any particular invention, four valuable contrivances to illustrate the character of domestic filtration now in use in this country, and which may be advantageously adopted in any dwelling.

DOMESTIC FILTRATION.

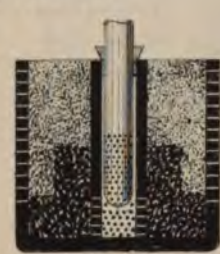
SKETCH SHEWING THE RELATIVE POSITIONS OF THE FILTERS.



SELF-SUPPLYING OXIDIZING FILTER.

THE NOSE-BAC FILTER.

Elevation.



Section.

BAILEY DENTON, SON & NORTH.
22 Whitehall Place, LONDON.

The "Spongy Iron Filter" is shown by *Fig.* 79. The filtering material used in this filter is that from which its name is taken—spongy (metallic) iron, which has been reduced from an oxide without fusion, and which is, therefore, in a spongy, porous condition, of extremely fine divisions, weighing about 100 to 110 lbs. per cubic foot. The filter is provided with a regulator (A) to govern the rate of filtration. The following example (taken from the Weekly Report of the Registrar-General) of the efficiency of this filter has been given me by the company who now possess the patent and supply the filter to purchasers. The figures given represent the constituents of the water in parts per 100,000.

Fig. 79.

Sample of water analysed.	Total solid impurities.	Organic carbon.	Organic nitrogen.	Ammonia.
Water before filtration	32·46	·139	·041	·002
Water after filtration	19·84	·028	·013	·130

The "Danchell Cistern Filter" is shown by *Fig.* 80. Its object and use are nearly identically the same as those of "the Nose-bag Filter" already explained, in Section XXXV., the difference being that the latter is placed in an underground tank or well, while the Danchell filter is placed in the service-cistern within the dwelling. The material em-

Fig. 80.

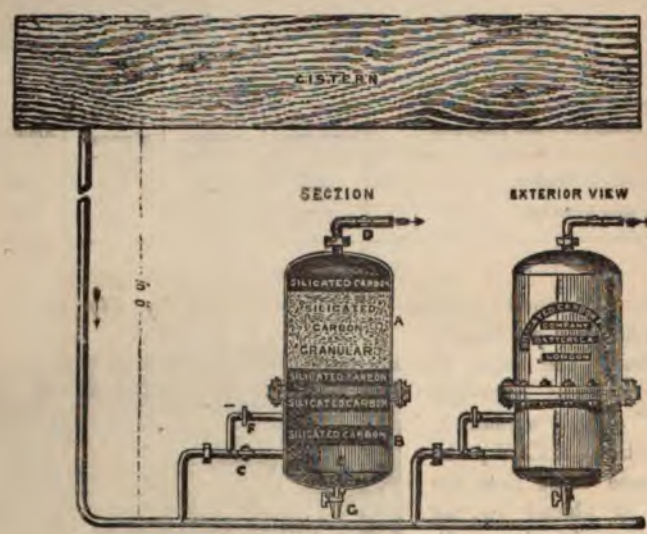
L

ployed to effect purification is animal charcoal, the vessel containing it being so arranged that the water passes from the bottom upwards, and is drawn off at the top. The following analysis (in parts per 100,000) has been supplied me by the London and General Water Purifying Company, who own the patent and sell the filter:—

Sample of water analysed.	Total solid impurities.	Organic carbon.	Organic nitrogen.	Ammonia.
Water before filtration	30·90	·104	·001	·015
Water after filtration	15·35	·07	Nil	·003

The "Silicated Carbon Main Supply Filter" is shown by *Figs.* 81 and 82. This filter is constructed in the form of a cylinder of stout

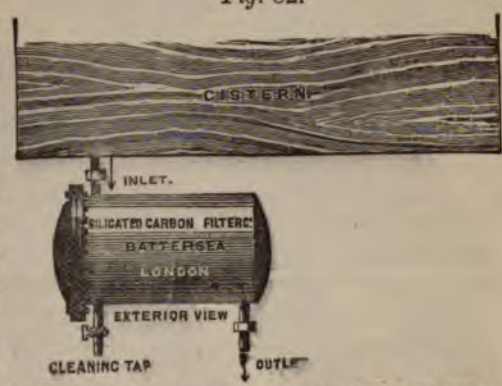
Fig. 81.



copper, lined with tin, the interior being fitted with slabs or plates of silicated carbon cemented into it, and the spaces between the slabs being filled with the same material in a granular form. The

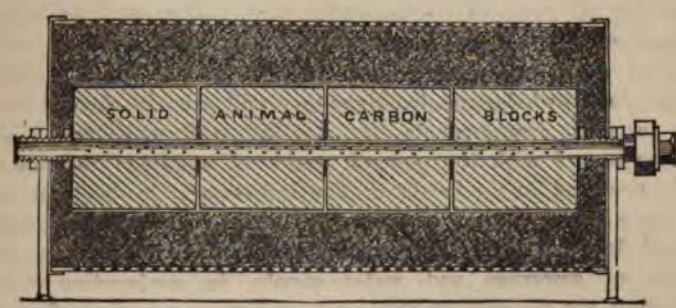
filter can be attached either to the service pipe after it has left the cistern (see *Fig.* 81), or to the cistern itself, as shown by *Fig.* 82. In either case it is declared to effect the perfect filtration of the whole water supply of a dwelling, and thus aims at the same effect without aëration as is undoubtedly gained by the intermittent aëration of the filtering material. The cleaning of this filter is effected by simply closing the outlet and allowing the water to pass freely through the cleansing tap G. This mode of filtration is said not only to remove organic impurities, but to render lead-poisoning by water impossible, "because"—the makers state—"it alters the chemical character of any salt of lead which may exist in water, and produces a compound which is insoluble."

Fig. 82.



The filter of Messrs. Atkins is shown by *Figs.* 83 and 84. The

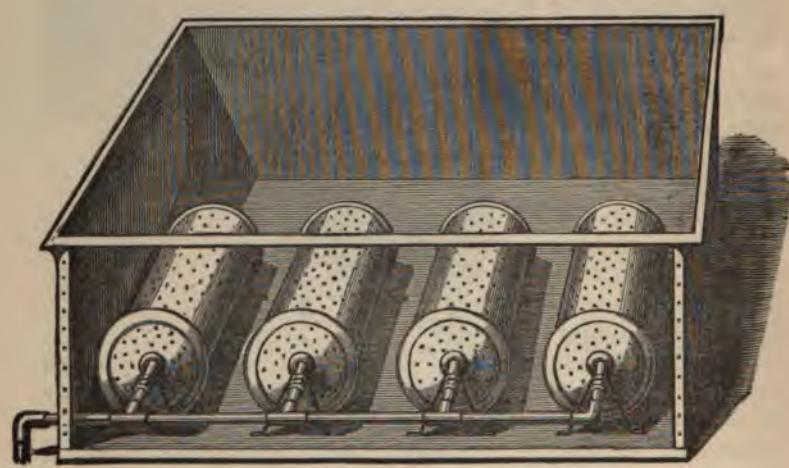
Fig. 83.



filtration is effected through animal charcoal in a block form (see

Fig. 83) placed in cisterns as shown in *Fig.* 84. The size of cistern

Fig. 84.



and number of cylinders are governed by the quantity of water to be used in the dwelling. They may each be increased as found necessary. Through the centre of each cylinder and block of carbon is a tube by which the filtered water passes out for use.

LXX.—Concluding Remarks on the Sanitation of the Dwelling. In closing my remarks on the duties of the Engineer in relation to the Dwelling, I desire emphatically to add that while pure air and pure water may give a good character to a town, a village, or a hamlet, unwholesome dwellings may still exist in them unless their internal arrangements are equally well considered and made to accord with the general works of sewerage and water supply provided for the locality. The influence of medical science has made itself felt on sanitary legislation, and the generally acknowledged necessity of providing for all *communities* proper systems of sewerage and water supply, in conjunction with scavenging, the removal of nuisances, and the prevention of overcrowding, has been the result. These works are already regarded as essential requirements in every district throughout the kingdom. At the same time, although the town, the village, and the

hamlet are only congregations of dwellings, the "dwelling"—which is "the unit of sanitary administration"—has been held sacred and free from the intrusion of the official sanitarian. Nevertheless, every dwelling, from the palace to the cabin, will, sooner or later, be subject, in some form or other, to the same influences, and their owners will be held to be legally responsible for the perfecting of those internal arrangements by which the pure air and pure water placed at their command may be turned to proper account. The tenants in their turn will be prevented from abusing those arrangements by inattention to proper maintenance. It remains to be seen whether the architect or builder will be considered responsible to his employer for the internal sanitary arrangements of the dwelling he designs or erects. Each dwelling will, I hope, be let with a certificate of its healthfulness, which the occupier will be obliged to respect by upholding its sanitary arrangements in the same condition in which he found them. Some objection and resistance will doubtless be raised by house-owners and speculating builders to such obligations, and the change I anticipate may not be immediate, but some change from the present state of things is so manifestly necessary that their resistance cannot long prevail. At present a very large proportion of the newly-built houses which are constantly springing up all over the country are without the proper sanitary appliances. Such as exist are quickly subject to derangement by their inferiority of material and construction, and it is impossible that any other conditions can prevail whilst so many Sanitary Authorities remain ignorant of their responsibilities, and their officers are incompetent to exercise the necessary control. At present many members of Local Boards consider that they best perform their duties to their constituents by doing nothing, and by delegating the important duties of Local Surveyor and Inspector of Nuisances to any tradesmen or neighbours who can bring local interest to bear on their appointments, without any reference to their ability to perform their duties. When local authorities become fully sensible of the necessity for increased vigilance, then—and not till then—will a different class of men occupy the offices of Surveyor and Inspector of Nuisances; and it is much to be regretted that there does not already exist a Court of Examiners where applicants for these important posts could undergo examination, and, if properly qualified, obtain diplomas of efficiency. Until this is done it is indeed difficult to say who are fit to investigate the sanitary condition of dwellings and furnish certificates of healthfulness, although no one who gives his attention to the subject will

deny that such certificates should be obtainable and would be as beneficial to the occupiers of private dwellings as the official reports by authorized inspectors are found to be in the case of prisons, lunatic asylums, and public institutions.

The following form an epitome of the principal objects to be aimed at in every dwelling to secure a good sanitary condition :—

1.—No cesspool, for the collection or detention of putrefying liquid refuse, should exist within or under any dwelling under any pretext whatever.

2.—No sewer should pass under any dwelling, if it can be possibly avoided.

3.—All soil pipes of water-closets should be thoroughly ventilated, as should also any pipe or space connecting the closet with the soil pipe, so that there may be no collection of sewage air under the pan or valve of the closet itself.

4.—All pipes from sinks and internal receptacles of slops should be disconnected from the sewer, and should discharge through the outer walls of the dwelling on to a trapped gully with grated covering.

5.—All solid refuse collected in or near the dwelling, should be removed at short intervals of time.

6.—The private sewer connecting the dwelling with the common (public) sewer, or with any "cesspool or other like receptacle," as well as all traps and gullies, should be thoroughly water-tight to protect the ground from pollution.

7.—All private sewers should be kept clear of deposit by flushing, and kitchen grease should be intercepted before it can enter the sewers.

8.—The ground under and surrounding the dwelling should be drained, so that there shall be no subsoil water within three feet of the foundations.

9.—All rooms and cellars in basements should be protected from the evils of uprising dampness by a layer of concrete under the floors, by damp courses in the walls, and by areas between the walls and the outer ground.

10.—No water that will not answer to the "attainable standard of purity" should be used for domestic purposes, and where possible water should be supplied direct from its source, or from a public main, without the use of any cisterns at all.

11.—No water should be stored in a cistern within the dwelling, unless it is satisfactorily filtered after it leaves the cistern.

12.—No water used for either drinking or cooking should be obtained from the same cistern as that from which water is directly drawn for water-closets and sinks.

POSTSCRIPT.—Country Houses. While revising these Lectures for the press, the present unsatisfactory condition of dwellings generally—both rural and urban—has recurred to my mind with increased force. My long connection with agriculture has taken me very frequently into the houses occupied by the owners of landed estates in all parts of the country; and, not unfrequently, the object of my visit has been the provision of better dwellings for the labourers employed on their estates, although the sanitary condition of the cottages it was intended to improve has been superior to the dwellings of the owners themselves. The observations I have been enabled to make, lead me to the conclusion that there is no class of dwellings which more positively demands sanitary re-organization than that which comprises the mansions of our country gentry, while I believe that there is no class of society that will less readily acknowledge the fact than that which occupies them.

Still I venture to state that it is only necessary that those who do so occupy them should examine for themselves,—(1) the state of the domestic offices, and the attics serving as dormitories,—(2) the condition of the wells, tanks, and cisterns from which the water used for drinking and household purposes is daily drawn,—(3), the way in which gases, more or less deleterious, find access by unventilated soil pipes and sink pipes from sewers and cesspits, into the rooms and passages frequented by themselves as well as their servants; and, further, that they should know the condition of the ground surrounding their dwellings, which is often kept saturated with sewage from leaky sewers mixed with roof waters, carried by down pipes into those sewers, to satisfy them that there exists a very different state of things from that which they have been led to believe is the case. Up to this time the warnings of medical authorities have hardly reached them, or those warnings have been evaded under the impression that the country house, being surrounded by a pure atmosphere, is proof against air pollution, and that, because they are isolated, the water drawn from shallow wells, sunk in close proximity to their dwellings, must necessarily be as pure as the air.

Surely there can be no greater mistake than this assumption. In the basements of many of the largest country mansions occupied by the most wealthy of our landowners, cesspools and sewers exist in number sufficient to render the superincumbent atmosphere

extremely unwholesome. In a majority of instances it will be found that the water used for drinking, cooking, and washing, will be obtained from wells in the neighbourhood of putrefying matter collected in cesspits and out-offices, or within reach of polluting liquid escaping from sewers and drains. Failing defilement before it is delivered into the dwelling, the water used will still be found to be more or less defiled by the foul condition of the service-cisterns within the dwelling, which, perhaps, have not been emptied nor cleansed for years, and which may, therefore, contain matter of a pernicious character.

Under any circumstances it will generally be found that there is an absence of proper filtration of water used for domestic purposes, and that the water closets and the kitchen boiler are directly supplied with water from the same cistern, and that, from a want of proper ventilation of soil pipes and closets—particularly where the latter exist in connection with sleeping apartments—the internal atmosphere of a country house may be rendered even more unwholesome than a town house, owing to the fact that in large country houses the principal bedrooms are only occasionally occupied, when the detention of putrefying matter in the traps of soil pipes increases the probability of sewer malaria.

No country house should be without a plan of its sewers, drains, and water pipes, conspicuously placed for the observation of servants, as well as superiors, and no pains should be spared to make every one understand that the sewers and sanitary appliances of a country dwelling require just as much care and attention as the public sewers of a large town. Further, it is most desirable to leave as little as possible to rectify by the village plumber, the only way of reducing his work to a minimum being simplicity of arrangement and accuracy of execution in the first instance, with a perfect record of pipes, &c., for after reference. In the absence of such a record as much money is expended in ascertaining the cause and position of anything wrong, as there is in putting it right when the defect is ascertained.

DIVISION IV.

THE TOWN AND THE VILLAGE.

LXXI.—General Observations on the Duties of the Engineer in relation to the Sewerage of Towns and Villages. The object of the sanitary engineer in his treatment of a town or village being the attainment of pure air and pure water for its inhabitants, he cannot confine his attention to the inhabited or covered portion of the district, but he must have regard to as much of the surrounding country as may have a direct or indirect influence upon his duties.

By the surrounding country, I mean that area which by the configuration of its surface, or by the nature of its subsoil, may rule the character and affect the cost of his works. The area which will have this direct or indirect influence will be limited to the basin or district which either physically or geologically will contribute surface and subsoil water; the first being that thrown off the surface tributary to the river, streams, or watercourses which form the natural drains of the district, and the second being dependent upon the character of the subsoil, and the dip or inclination of the underlying strata.

Every undulation within the area contributing surface waters has an influence on the position and size of the required sewers, and helps to determine the extent to which surface waters shall be admitted into the general system; while the geological features of the district, the depth of the underground water, and the nature of existing springs, enable the engineer to foretell the effect of an imperfect construction of sewers, against which it is his duty to provide, knowing, as every practised man does, that to secure a perfectly water-tight condition of sewers is a work of extreme difficulty.

In his preliminary investigation the engineer will necessarily ascertain, too, the character of the trades existing in the district with

which he has to deal, and the occupation of its population generally, as both these considerations affect the character of the refuse.

He will also examine carefully the nature of the material of which the streets and roads are made, the detritus from which will form an important item when deciding to what extent the surface waters shall be permitted to mix with the liquid sewage.

He will further have special regard to the ultimate destination of the sewage — whether it be directly into the sea, into tidal water, or into an inland river—for upon this point will depend the means by which the sewage will be cleansed before it is discharged.

LXXII.—Surface Waters, and their Admission into, or Exclusion from, Sewers. To ascertain the amount of surface water to be admitted into the sewers, or to be discharged by separate surface drains, it is necessary to have regard to the rainfall of the district, and the maximum downfalls to which it is subject. The great difference in annual rainfall which prevails in one part of England as compared with another has been already pointed out (see Section XX.), and it may be taken for granted that the amount and frequency of heavy rains vary somewhat in the same proportion,—the large downfalls of the west, for instance, being as much greater and as much more frequent than those of the east, as the annual rainfall of the west exceeds that of the east. In many districts of the north, as well as of the west, where the older geological formations exist, the inclination of the surface is precipitous, the soil is non-absorbent, and the heavier rainfalls are frequent. With such coincident features the rain is thrown off the surface in excessive amounts, and with great rapidity. On the eastern side of the country where wide areas of sand, chalk, and oolite outcrop, the reverse conditions prevail; the surface inclinations are moderate, the soil for much the greater part is absorbent, and excessive rainfalls are of comparatively rare occurrence. In the first case it may be laid down as a rule that the surface waters should be excluded from the sewers to a very considerable extent, while in the second a sensible portion may be admitted with advantage. If a proper regard is paid to economy in sewerage works, in no case will it be found advisable to exclude from the sewers the *whole* of the surface waters.

It is in fact with considerable difficulty that the engineer arrives at the amount of surface water for which he must provide in one way or another, by admission into the sewers or by discharge through surface drains.

The plan adopted by Sir Joseph Bazalgette when providing for the

rainfall of the metropolis, is suggestive of the kind of investigation which should be made in every case. He ascertained by careful inquiry and examination of records that, on an average of years, rain fell in London for about 155 days per annum, and that of these there were only about 25 upon which the quantity amounted to a quarter of an inch in depth, and of such rainfalls he discovered that a large proportion was evaporated and absorbed, and either did not pass through the sewers at all, or did not reach them until after the rain had ceased. A commission, consisting of Mr. Bidder, Mr. Hawksley, and Sir Joseph Bazalgette, conjointly investigated this point, and the conclusion ultimately come to was that the rainfall should be admitted, and that a quantity equal to one hundredth part of an inch in an hour, or a quarter of an inch in twenty-four hours, was all that need be provided for;—and a quarter of an inch of surface waters in twenty-four hours represented the provision which was made.

I am not laying it down as a rule that the engineer in every case is bound to collect the same details which governed the works of the metropolitan sewerage; but I desire it to be understood that he should in no case omit such an investigation altogether. In the metropolis all excess of rainfall collected by subordinate sewers beyond the quantity provided for in the main sewers passes away into the River Thames by storm overflows, constructed at the junctions of the intercepting sewers with the cross valley lines of sewers. This is justified by the fact that the river is tidal, and that the influx of storm water on occasions of heavy rainfalls cannot materially affect the quality of its water.

By reference to the amount of monthly and annual rainfall (see Section XX.), to which I have just referred, the difference between the rainfall of London and of other parts of the country will be seen, and the extreme difficulty of dealing with any fixed proportion, such as that admitted by Sir Joseph Bazalgette into the metropolitan sewers, will be recognised. If, in fact, we were not to treat very differently the inland towns of the west and north of England to those of the east and south, we should find the quantity of diluted sewage so formidable as to forbid the execution of any system of sewerage and sewage disposal aiming at the effectual prevention of river pollution. With towns already sewered, without reference to the cleansing of their sewage, this same difficulty arises.

If we recognise, as we certainly ought, a difference between towns situated in districts of rapid inclinations, impervious surfaces, and heavy rainfalls, and those where the reverse conditions prevail,

it will be considered advisable to admit into the sewers of the former only such rain as falls on the back portions of the roofs of dwellings —on impervious surfaces so situated that it would be difficult to connect them with any system of surface drainage—and on those streets, courts, &c., which from their situation collect refuse almost as foul as sewage itself. In the latter class of towns, *i.e.*, those with flat inclinations, porous surfaces, and smaller rainfalls, it is better not only to admit the rain falling on the back portions of roofs, back yards, &c., but such an additional quantity as may be advantageously turned to account for flushing the sewers without increasing the cost of the necessary works.

I need hardly repeat more emphatically than I have already done, that the mode of disposing of the sewage must have a predominant influence in ruling the admission or exclusion of surface waters. If the interception and discharge of the sewage can be effected by gravitation, the objection to the admission of surface waters is to some extent reduced; whereas, if the whole of the contents of the sewers has to be lifted in order to be freed of its noxious matter before discharge into the rivers, any increase of quantity by the addition of storm waters becomes a matter of considerable moment. So with regard to the cleansing of the sewage; it will be readily understood that the occasional dilution of the "sewage-proper" by surface waters, amounting to four or five times its quantity, would defeat both an economical treatment and an effective cleansing of the sewage. This will be obvious when we call to mind that with a town of 20,000 inhabitants, consuming and converting into sewage 25 gallons of water per head, per diem, the quantity of sewage-proper will be only 500,000 gallons, of which the maximum outflow for six hours in the day may be equal to one-half the day's discharge, or 694 gallons a minute, while if only a quarter of an inch of rain be run off a contributing area of, say, 500 acres in 24 hours, the quantity of surface water would be equal to 1,963 gallons per minute (or 2,827,500 gallons per diem), which is nearly three times the maximum outflow of the sewage-proper. And if instead of a quarter of an inch, the proportion to be admitted was half an inch, the maximum outflow would reach six times the maximum outflow of the sewage-proper.

The cost of constructing an outfall sewer to meet this requirement would be of itself an item of considerable importance; but it would be small compared with the cost of pumping in wet weather, or with the increased cost of dealing with such diluted sewage after it had been raised,—to say nothing of the cost of rectifying the injury

done to sewerage systems when these large influxes put the sewers under pressure and drive the jointing—particularly clay jointing—out of the pipe sockets. These are circumstances weighty enough of themselves to influence the engineer when deciding the extent to which surface water shall be admitted into sewers, though when the outfall sewers are either tide-locked, or are used as reservoirs for the collection of sewage during the night, and at times when it is desired to cease from pumping, he will recognise more cogent reasons still for exclusion, inasmuch as the diluted sewage crowding into these reservoirs rises from the main into the minor sewers on occasions of heavy rainfall, and from them finds its way to the foundations and cellars of low-lying dwellings. When this is the case the internal pressure of the sewage becomes so great that if there is any flaw in the construction of the sewers, or if they are jointed with clay, the sewage readily escapes into the surrounding soil, and causes the sanitary evils to which reference has been already made (see Section XLVI.) It will be obvious, too, that as the surface waters fill these sewers and reservoirs, they force out the air that is in them, which rises and finds vent by every shaft and trap that will allow of its exit, whether it be into streets or into dwellings. In many of our more fashionable sea-bathing towns (see Section LXXX.) this condition prevails, and the higher parts (where the better houses are built to secure better air) are subjected to the uprising of effluvia from the lowest sewers. It is so, I believe, at Brighton, and at many other places, where people congregate for ***health***. I refer to this condition of things at our sea-bathing places because there would appear to be no excuse for its existence in towns which are dependent upon visitors in search of *fresh air* for the means by which their inhabitants chiefly subsist. *Leaky* sewers to pollute the soil and cause malaria, and *impounding* sewers to generate and give out deleterious gases should in these cases above all others be avoided instead of trusting to the salutary influences of the sea to counteract such evils;—and when advancing knowledge has convinced all persons alike that it is dangerous to adulterate pure air with foul, the public will doubtless make the selection of those seaboard towns which are free from such drawbacks. I recognise a difference between reservoir-sewers constructed *within* an inland town with frequent junctions with private communicating sewers and those forming a portion of outfall sewers *without* the district having no junctions to give off effluvium into private dwellings, but specially ventilated in themselves.

TABLE showing—(1) the Depth of Rainfall converted into Numbers of Tons, Cubic Feet, and Gallons per Acre, and (2) the Quantity per Minute for which Provision must be made in the Sewers for every Acre contributing its Surface Water to such Sewers.

RAINFALL.					Quantity to be provided for in the Sewers for every Acre of Contributing Surface.			
Depth over Surface.		Quantity falling on each Acre.			When Half reaches the Sewers in the Day of 24 Hours. Per Minute.		When One Quarter reaches the Sewers in the Day of 24 Hours. Per Minute.	
	in. dec.	tons. dec.	c. ft. dec.	gallons.	c. ft. dec.	galls. dec.	c. ft. dec.	galls. dec.
Frequent	·010	1·01	36·3	226	·012	·078	·006	·039
	·015	1·51	54·4	339	·018	·117	·009	·058
	·020	2·02	72·6	452	·025	·157	·012	·078
	·025	2·52	90·7	565	·031	·196	·015	·098
	·030	3·03	108·9	678	·037	·235	·018	·117
	·035	3·53	127·0	791	·044	·274	·022	·137
	·040	4·04	145·2	904	·050	·314	·025	·157
	·045	4·54	163·3	1,018	·056	·353	·028	·176
	·050	5·05	181·5	1,131	·063	·392	·031	·196
	·055	5·55	199·6	1,244	·069	·432	·034	·216
	·060	6·06	217·8	1,357	·075	·471	·037	·235
Occasional.	·065	6·56	235·9	1,470	·081	·510	·040	·255
	·070	7·07	254·1	1,583	·088	·550	·044	·275
	·075	7·57	272·5	1,697	·094	·589	·047	·294
	·080	8·08	290·4	1,809	·100	·628	·050	·314
	·085	8·58	308·5	1,922	·107	·667	·053	·333
	·090	9·09	326·7	2,036	·113	·707	·056	·353
	·095	9·59	344·8	2,149	·119	·746	·059	·373
	·100	10·10	363·	2,262	·126	·785	·063	·392
	·200	20·20	726·	4,524	·252	1·570	·126	·785
	·250	25·25	907·	5,655	·315	1·963	·157	·981
	·300	30·3	1.089·	6,786	·378	2·356	·189	1·178
	·400	40·4	1.452·	9,049	·504	3·141	·252	1·570
Extraordinary.	·500	50·5	1.815·	11,311	·630	3·927	·315	1·963
	·600	60·6	2.178·	13,574	·756	4·712	·378	2·356
	·700	70·7	2.541·	15,836	·882	5·497	·441	2·748
	·800	80·8	2.904·	18,098	1·008	6·283	·504	3·141
	·900	90·9	3.267·	20,360	1·134	7·068	·567	3·534
Very extraordinary.	1·000	101·	3.630·	22,622	1·260	7·854	·630	3·927
	2·000	202·	7.260·	45,244	2·520	15·708	1·260	7·854
	3·000	303·	10.890·	67,866	3·781	23·563	1·890	11·781

I have always considered that the mixture of sewage with rainfall which now indiscriminately prevails, is wholly due to the same want of forethought which failed to anticipate the effect of turning our rivers into sewers, and which followed the passing of the Act of 1848. Still there are some engineers of eminence who continue to favour the admission of the whole of the surface waters of a town into the sewers; and the principal ground for the practice is the opinion given by Professor Way (when speaking of London), to the effect that "considering only the composition of the liquid which reaches the sewers in times of rain from the streets, it seems pretty certain that it would be as valuable in a manurial point of view as the ordinary contents of the

sewers." In certain crowded districts this condition doubtless does exist, and it will be only properly met by admitting into the sewers the surface waters so defiled—taking care, however, that the remainder which is not polluted in the same way shall be discharged by independent channels into the river or stream, which forms the natural drain or outfall of the locality.

When drawing the line of demarcation required to secure the "rain to the river and the sewage to the land," the off-flow from filthy streets of thickly populated towns, therefore, must be treated differently from the main portion of the rainfall. The argument that, because the off-flow from certain streets and roads is frequently foul, the sewers are the only fit place for the whole of the surface waters, loses much of its force when it is remembered that on every occasion of an excessive downfall of rain the storm-overflows, which every engineer provides as safety valves, must come into requisition, and that then both rain and sewage find their way together to the river.

A consideration of these facts has led me in every case to make a liberal provision in the sewers for surface waters, and to trust to storm overflows in sufficient number as a means of removing any difficulty that may arise when the provision fails to satisfy an extraordinary influx, knowing that they come into action only at those times when the swollen condition of the rivers must render any increased pollution a matter of comparatively little consequence. Some of the plans which have been adopted for admitting a certain proportion of the rainfall only—*i.e.*, the first or foulest portions of heavy downfalls, and the whole of slight showers—into the sewers, and for the exclusion of the remainder, will be dealt with under the head of storm overflows, Section LXXXV.

LXXIII.—Road Detritus, and its Influence upon the Disposal of Sewage. The question what shall be done with the detritus which is washed in greater or less quantity from all roads and streets, is of great importance in the economy of sewage disposal.

In some districts where the material of the roads is easily disintegrated, it becomes an object of the very first consequence. At Birmingham, for instance—which you will remember is in the heart of the red sandstone district—the quantity of road detritus which has to be dealt with at the outfall in one way or another amounts to a very considerable quantity. Mr. Till, the borough surveyor, says: "Our tanks gave us, for the year 1875, an average of 360 cubic yards of mud per diem. We use about fourteen tons

of lime per day; a large proportion of this never reaches the outlet tanks at all, but has to be removed from the 'mixers' and carted away, whilst another proportion passes off with the effluent. My figures include the lime deposited in the tanks. I believe the intercepted mud contains above 80 per cent. of water; the road detritus is enormously increased by rain (in dry weather we get hardly any) You are aware our roads are mostly macadamised." This average daily quantity of collected solid matter would appear by this to amount to about 70 cubic yards;—part of which is removed and sold as sand as it is raised from the depositing tanks, while the remainder (the sludge) is spread when in a semi-liquid state over the surface of land laid out and enclosed by banks in the form of beds to receive it. When nearly dry this latter portion is dug into the land, and being perishable is gradually absorbed. Birmingham is an extraordinary instance, and the proportion of road detritus discharged by its sewers can hardly be exceeded, and probably cannot be equalled by any other town in England, but the figures quoted will be useful in showing the advantage of excluding road detritus from sewers.

This remark will equally apply when the sewage is applied to land or is chemically treated, for the greater the quantity of detritus mixed with the sewage, the greater the difficulty of treating it, and the less must be its manurial value.

Road detritus, if it is freed from putrescible matter, and from the salts of sewage, may sometimes be turned into money as material for mortar or for foundry sand, or as ballast. Builders, however, generally decline to use it when it has been once mixed with sewage, because it is stated the salts left from the sewage injuriously affect the mortar.

The difficulty of disposing of road detritus forms a sufficient reason why special arrangements should be made by catchpits in connection with surface drains for the collection of this material, which, as I have said, is valuable of itself, but which becomes worse than valueless when it finds its way into rivers to raise their beds and so impede navigation and increase floods. This last consequence I consider of very great moment. I cannot better support the view I entertain of it than by directing your attention to the large amount of solid substances which is being discharged from the sewers of the metropolis at Barking and Crossness, and which must be deposited in the bed of the lower reaches of the Thames.

A Commission was appointed in France in 1874, by the Minister of Public Works, to inquire into the best means of remedying the pollution of the Seine, and one of the first points to which attention

was given was the effect of the deposit of road detritus in the bed of that river. The result of the examination was the discovery of a state of things very similar to that which must inevitably exist in the Thames, though tidal, between Woolwich and the Nore. The Commisssioners state in their reports dated the 12th December, 1874:

"Abordant l'examen des remèdes à apporter à la situation présente, la commission, sous réserve des procédés plus radicaux qu'elle examinera ci-dessous, doit insister sur l'absolue nécessité de continuer les vigoureux draguages qui combattent l'encombrement de la Seine aux embouchures des collecteurs : indépendamment des questions de salubrité publique, il y a là une nécessité urgente au point de vue de la navigation. On a vu, dans la première partie du rapport, que les collecteurs versent en Seine, par an, 150,000 tonnes en poids de matières solides, soit un volume vaseux de 200,000 à 300,000 mètres cubes. Les parties les plus lourdes forment les bancs qui émergent périodiquement et que le service de la navigation a dragués depuis quelques années dans les proportions suivantes :

	Mètres Cubes. Nombres Ronds.
1868	69,000
1869	58,000
1870	57,000
1871	64,000
1872	66,000
1873	82,000

"En 1874, le budget de la ville de Paris portait un crédit de 180,000 fr. pour les draguages aux embouchures des collecteurs. Mais ces opérations, exécutées sur les saillies des bancs d'atterrissement, appliquées du reste à des cubes inférieurs à l'apport annuel des collecteurs, ne peuvent éviter le comblement des bas fonds et l'encrassement progressif du lit du fleuve par les vases et les matières organiques légères : de là l'extension et l'accroissement annuel des phénomènes de fermentation dans les profondeurs mêmes du courant, pollué à la surface par les matières fermentescibles dissoutes. La commission ne saurait donc voir dans les draguages qu'un palliatif provisoire dont elle recommande l'application incessante, mais qui ne peut, à aucun titre, être érigé en solution de la question."*

* The following is a translation of the extract given:—

"In proceeding to examine the remedies to be applied to the present state of things the Commission, without going into the more radical measures, which will be examined hereafter, must insist on the absolute necessity of continuing a vigorous course of

The substances held in suspension and reaching the mouths of the great rivers of Asia and America, we all know, form delta there—making fresh land, in fact, in a natural manner, just as the minute débris of the red sandstone district form artificially a valuable deposit by the process of warping on the banks of our own river, the Humber. I believe we may assume that as certainly as these formations are now taking place, so the deposit of the detritus of the roads of London in the Thames will cause a serious and irreparable injury to the port of London, which no amount of dredging will be able altogether to remove after some more years of continuance. Such an effect of Sir Joseph Bazalgette's truly admirable work—the metropolitan sewerage—would be lamentable indeed.

LXXIV.—Subsoil Water and its Admission into, or Exclusion from, Sewers. As already intimated, one of the greatest difficulties which an engineer has to contend with is the existence of subsoil water in the ground through which he has to lay his sewers, inasmuch as any joints which are not water-tight not only admit that subsoil water to dilute the sewage, but after the water in the surrounding soil is lowered, the sewage which should be confined to the sewer will under any appreciable pressure find its way through the same interstices into the soil. This I have ventured to condemn as an objectionable result on sanitary grounds, although it is not so regarded by some engineers. (See Section XLV.). The effect produced by this bad workmanship is nevertheless beneficial to some

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dredging to prevent the blocking up of the Seine at the mouths of the outfall sewers. Independently of the question of the public health, this is an urgent necessity on account of the navigation of the river. It has been shown in the first part of the report that the outfall sewers discharge into the Seine annually 150,000 tons of solid matter, or a volume of mud of from 200,000 to 300,000 cubic metres. The heavier substances form banks which periodically rise above the surface of the water, and which the Navigation Service has dredged for several years in the following quantities:

	Cubic Metres. (In Round Numbers.)
1868	69,000
1869	58,000
1870	57,000
1871	64,000
1872	66,000
1873	82,000

In 1874 the budget of the city of Paris showed a debt of 180,000 francs for dredging at the mouths of the outfall sewers. But these operations cannot prevent the filling up of the bed of the river and the gradual pollution of its bed by filth and light organic matters. It is from this cause that we obtain the annual extension and increase of the phenomena of fermentation even in the deepest part of the river, the water of which is polluted to the surface by dissolved putrescible particles. The Commission can therefore only look upon dredging as a temporary remedy, of which they recommend the incessant application, but which cannot, under any circumstances, be held up as the solution of the question."

extent, for, as I have shown, the lowering of the subsoil water in the ground, which is one of the first objects to be aimed at in sanitary works, is indirectly gained by it. (See Sections XII., XLIV., and XLVI.)

Sewers should without any doubt be made water-tight, and where subsoil water exists to the injury of the health of the locality, it should be removed by an independent subsoil drain. It must not, however, be considered to be invariably an additional work, for wherever a contractor has to deal with subsoil water he invariably places a drain of a temporary kind under the permanent sewer for the purpose of withdrawing the water which would otherwise interfere with its construction. Whatever be the cost of this temporary work to the contractor he practically recovers it in the advantage it is to him, and a very little addition to the cost of the sewer will cover the construction of the subsoil drain in such a way as to serve as a permanent rather than a temporary work only.

To illustrate what such an addition to the cost of the permanent sewers will be, I may point out that the subsoil water of towns of the size of York, Birkenhead, Chester, Bath, Southampton, Cambridge, Oxford, and Ipswich,—supposing every acre to be more or less wet, and to require under-drainage,—may be removed at a cost which if reduced to a rate on the inhabitants, would not amount to a halfpenny in the pound, and if you refer back to the number of deaths which I stated to be due annually to diseases that may be to a great extent reduced, if not altogether avoided, by drying the soil upon which dwellings stand (see Section XLIV.), you will find it difficult to reconcile with sound economy the absence of systematic drainage in addition to systematic sewerage.

In practice it will be frequently found that whenever the main or intercepting sewer conveying the sewage to a pumping station is below the level of the outfall river, and the ground water has to be collected by an under-drain during construction, the water level may be permanently lowered, and the pressure upon the sewer reduced, by securing an outlet for the subsoil water, after it has risen in a shaft for the purpose, at the lowest attainable point.

I need hardly say that when pumping is resorted to, every gallon of water finding its way into the sewers from the subsoil will add to the cost of the pumping, and that any mode of treating the sewage to free it of its foul matters—chemical precipitation suffering even more than land cleansing—must be injuriously affected to the extent to which the sewage is diluted. It will be admitted, nevertheless, that the sewerage of towns having a very limited

water supply may be improved by the influx of subsoil water for cleansing the sewers; but inasmuch as the difficulty of making any system of sewers altogether water-tight is insuperable where there are junctions with *private* communicating sewers, there will always be a sufficient influx from a constantly wet subsoil to keep the common sewers self-cleansed, even though every effort has been made to make them water-tight.

When Professor Pettenkofer declared that "waterproof sewers exist only in the imagination of those theorists who consider hydraulic lime and waterproof to mean the same thing," he stated that the quantity of nitrogenous matter that escaped out of the sewers by the same apertures that admitted the subsoil water into them was so great that in one cubic foot the quantity of organic nitrogen amounted to 122 grains. Does not this illustration of the evils of faulty sewers point out to the engineer the advantage of doing all that can be done to render sewers water-tight and to a great extent explain the foul condition of the soil beneath our public offices in Whitehall, of which much has been recently said?

It is because it is impossible to render sewers altogether water-tight when laid in wet ground, that the engineer should provide in his sewers for a certain amount of dilution by subsoil water, the exact quantity to be provided for being determined by the circumstances of each case.

That the effect of imperfect sewers laid in wet ground in increasing the quantity of liquid discharged, may be appreciated by ratepayers as well as engineering students, I may mention that the cost of lifting 1,000,000 gallons of sewage daily to a height of 50 feet does not at this moment amount to less than 450*l.* a year; and that the influx of as much as 1,000,000 gallons of subsoil water into the sewers of a town is not a mere assumption, will be seen from the following figures abstracted from the second report (1871) of the Sewage Committee of the British Association, giving the total average water supply, and the total ordinary dry weather daily outflow from the sewers (exclusive of storm waters):

Name of Town.	Water Supply.	Discharge of Sewers in Ordinary Dry Weather.
	Gallons.	Gallons.
Glasgow	21,600,000	35,000,000
Liverpool	12,750,000	25,000,000
Dover	1,038,740	3,438,740
Cardiff	1,000,000	2,500,000
Leicester	1,780,000	3,000,000
Torquay	610,000	1,600,000

I have been in communication with the engineers of several towns upon this subject.* At Carlisle, where the water supply, including that used for trade and public purposes, amounts to 1,061,000 gallons daily, Mr. Morley informs me that the quantity of sewage discharged is upwards of 2,000,000 gallons, owing to "a large quantity of water entering into the outer districts." Of Bedford, Mr. Lund states that the daily flow of sewage from the sewers is about 700,000 gallons, which it will be seen by the Table given in Section XIX. is double the water supply. At Salisbury, Mr. Bothams says: "The outflow of sewage, &c., here is very greatly in excess of the water supply, owing to the subsoil drainage; the lower end of the main sewer passes through some water meadows with an open gravel subsoil full of water, which enters through the joints of the invert blocks of the sewer. The same occurs to some extent at the lower part of the town, varying with the level of the springs. The outfall is generally a few inches below the level of the river into which it discharges, except in summer when the river is low."

Before closing my remarks upon subsoil water I should state that, though, as a rule, the common sewer and the subsoil drain may occupy the same trench, there are some instances in which it would be injudicious to lay a subsoil drain immediately below a sewer, while there are others where it might be more economical to lower the subsoil water by drains altogether independent of the sewer.

LXXV.—Quantity of Sewage dependent on present and future Population—on Local Trades and the Occupations of the People—and on the Water Supply of the District.

(1.) *Sewage due to Population.*—When ascertaining the number of people who contribute sewage, and for whom water has been provided—which water, in fact, becomes sewage after it has been used in the dwelling, the factory, or the shop—it is necessary to consider with care also how far circumstances may alter the conditions of the town or village for which sewers have to be designed. Places which suddenly rise into importance like New Swindon, Crewe, and North

* I am much indebted to the several engineers of Exeter (Mr. Boulnois), Salisbury (Mr. Bothams), Birkenhead (Mr. Thorburn), Southampton (Mr. Lemon), Plymouth (Mr. Bellamy, Engineer to Water Works), Bath (Mr. Mitchell, Engineer to Water Works), Huddersfield (Mr. Abbey), Barnsley (Mr. Kenworthy), Carlisle (Mr. Morley), Bolton (Mr. Proctor), Warwick (Mr. Pritchard), Cheltenham (Mr. Humphris), Darlington (Mr. Reah), Hastings (Mr. Andrews), Brighton (Mr. Lockwood), Bedford (Mr. Lund), Wolverhampton (Mr. Morgan), Margate (Mr. Albert Latham), and Leamington (Mr. Davidson), for their courtesy in replying to inquiries.

Peterborough, which towns the railways may be said to have created defy the most far-seeing anticipation, and the most careful calculation both as to population and the purposes for which water may be used. There are other towns, such as Middlesbrough, Newport in Monmouthshire, Burnley, and Bradford, where, owing to the development of special trades, the rate of increase has been as marvellous. On the other hand, towns situated at a distance from railways, and therefore wanting in the means whereby they may compete with other towns, have increased comparatively slowly in their populations. The following Table exhibits the rates at which some of the most rapidly growing towns have increased in population, within the period of a lifetime,—since the beginning of the present century.

NAME OF TOWN.	Special Character or Trade of Town.	Population.		Increase per Cent. during 50 Years, 1801-1851.	Population in 1871.	Increase per Cent. during 20 Years, 1851-1871.	Total Rate of Increase per Cent. since Commencement of Century, 1801-71.
		1801.	1851.				
Middlesbrough	Shipping—coal and iron export	239	7,893	3203	39,563	401	16,453
Liverpool	Shipping	82,295	375,955	357	493,405	31	500
Torquay	Sea-side resort	838	11,474	1270	21,657	88	2,484
Brighton	" "	7,440	69,673	836	90,011	29	1,110
Leamington	Mineral waters	315	15,724	4891	20,910	33	6,538
Cheltenham	" "	3,076	35,051	1040	41,923	20	1,263
Newport (Monmouth)	Iron and coal	1,423	19,323	1258	27,069	40	1,802
Bradford	Woollen, yarn, &c.	13,264	103,778	682	145,830	40	999
Barnsley	Coal	3,606	14,913	314	23,021	54	538
Burnley	Cotton and woollen works.	3,918	20,828	432	40,858	96	943
Preston	Cotton mills	12,174	69,542	471	85,427	23	603
Derby	Silk, cotton, and porcelain works	10,832	40,609	275	49,810	22	360
Stoke-on-Trent	Pottery works	23,278	84,027	261	...	...	...
Birmingham	Metal manufactories	70,670	232,841	229	343,787	48	386
Sheffield	Cutlery trade	45,755	135,310	196	239,946	77	424
Rotherham	" and coal and iron trade	6,579	13,543	106	25,892	91	294

If we take a more general view, the census will show us that the total population of England and Wales has been doubled within a period of fifty years. Looking upon this as a datum, it will be for the engineer to determine whether the provision which he should make in his sewers should have reference to this or to any greater or less ratio of increase.

Besides the population of the town under immediate considera-

tion, it will be frequently found necessary to provide for the sewage of suburban parts not yet included in it.

(2.) *Sewage affected by Local and Special Trades.*—In determining the capacity of the sewers of a town it is essentially necessary that it should be previously decided how far the liquid refuse of local and special trades shall be admitted into them.

The amount of water used in some descriptions of trade is very great. One manufactory will serve as an illustration, though it is doubtless an extreme one. The quantity of water used in the case I refer to actually reaches nearly two millions of gallons daily —a quantity equal to the water supply of an ordinary town of 80,000 inhabitants! In some of the manufacturing towns of the North and West of England, the quantity of water used in trade forms a very appreciable portion of the total supply. (See Sunderland and South Shields, Darlington, Bacup, Leicester, Birkenhead, Lincoln, and Plymouth, in Table of Water Supply, Section XIX.)

To convey an idea of the pollution to which the water may be subject when used in certain trades, it may be stated that in the case to which I have referred, the water used for washing is 248 millions, for bleaching 62 millions, for printing 31 millions, and for dyeing 93 millions of gallons per annum, and that the substances used in the works are, for dyeing 450,000 lb. of madder and dye woods, and for bleaching 162,000 lb. of lime, 24,000 lb. of bleaching powder, 234,000 lb. of soda ash, 34,000 lb. of caustic soda, 61,000 lb. of resin, 245,000 lbs. of muriatic acid, and 30,000 lb. of sulphuric acid per annum, besides soap.

Numberless are the cases in which such "polluting" materials are used in trades, though the quantities may be much less. The particular case quoted simply serves to show the difficulties that may have to be contended with now that trade liquids are considered admissible into sewers.

The amount of pollution caused by different trades may be further illustrated by comparing the quantity of organic nitrogen contained in the liquid refuse discharged from them with that given in the standards proposed by the Rivers Pollution Commissioners, as the amount which they recommended should govern the admission of all liquids into streams, viz., ·3 in 100,000 parts. The same Commissioners found by analysis that the quantity of this ingredient (the primary indication of impurity) contained in the liquid discharged from a paper mill was 76·816 parts, from a woollen mill 14·380 parts, from a Witney blanket mill 19·508 parts,

and from a flannel mill 91·185 parts in 100,000 parts. The average of fifteen cases of pollution by woollen and cotton mills given by the same authorities was 10·384 parts of organic nitrogen in 100,000 parts. I must refer you for further details to the tabular statement of the composition of liquid refuse from different trades subsequently given in Section XCI.

These quantities of *organic* matter, if admitted into sewers, would not in all probability militate against the utilisation of their contents upon land, nor their conversion into dry manure by chemical processes, the difficulties attending their admission being simply due, as far as we know, to the amount of dilution. There are trades, however, such as galvanising works, German silver works, brass and copper works, chemical works, gas works, and mines, which use and discharge ingredients of a nature positively destructive to vegetation, and which, therefore, if admitted into the sewers, would preclude the possibility of the sewage of the town being utilised upon land, or converted into a dry manure. It would appear, therefore, to be only just that those persons who derive a profit from the trades which create these special difficulties should themselves be called upon to free the water they use of its deleterious matters, and intermittent downward filtration, as pointed out by the Rivers Pollution Commissioners, offers special facilities for dealing with the liquid refuse of some of these trades. (See Section CI.)

The Legislature has very properly thought proper to protect individuals who make use of common sewers for the discharge of their liquid refuse into streams against legal proceedings under the Rivers Pollution Prevention Act, provided they have the sanction of the sanitary authority of the district, and the consequences of this provision it is hard to foresee, (see Part II., 39 and 40 Vict. c. 75, sec. 3), and under the same Act, section 7, every sanitary authority is obliged to give facilities for enabling manufacturers within their district to carry their liquid refuse by private communicating sewers into the common sewers, provided it is of a character or of a temperature not to prejudicially affect the system adopted for the disposal of the sewage from an economical or sanitary point of view.

(3.) "*Sewage Proper*" *equal to Water Supply.*—To arrive at the quantity of water converted into liquid sewage by any community, it is necessary not only to ascertain the precise amount supplied by the sanitary authority (if the water works be vested in that body) or by the water company serving the district, but to estimate also what quantity is derived from private wells and other sources.

The sum of these several means of supply, however, may not re-

present the quantity which the engineer will consider it right to take as the measure of the sewage to be dealt with.

Where the quantity is less than 25 gallons per head per diem in towns, or 15 gallons per head per diem in villages, it is always safer to consider that these figures, rather than the actual consumption, should represent the quantities for which we must provide in anticipation of the increasing use of water in all private establishments and the growing requirements of a public nature now making themselves felt.

In addition to this there will be the water utilised in local and special trades which is, or may be, admitted into the sewers, and to which I have just referred. These contributions together represent the sewage of the district. Some useful and suggestive figures on this point will be found in the tabular statement of water consumed in England and Wales, given in Section XIX.

LXXVI.—Variation in the Discharge of Sewers—Maximum and Minimum. In determining the size of the sewers by which the liquid refuse will be discharged, it is necessary to have reference to the varying outflow of sewage from dwellings at different times of the day. This is found to accord with the occupation and trades of the inhabitants of each place. One town will differ much from another in its domestic arrangements, and in the time when water is used for trade purposes.

A frequent practice amongst engineers is to consider that one-half the daily outflow will be discharged in six or eight hours, and the remainder in the sixteen or eighteen hours making the day. The quantity discharged during the night, from ten P.M. to eight A.M., will be the minimum, the actual amount depending upon the construction of the sewers. If they are water-tight the discharged quantity will be very little in ordinary towns of the east and south of England, while in mining districts, where the population is active during the night, the outflow will be copious and nearly as foul as in the daytime. (See Merthyr and Wolverhampton in the next Table.)

When, therefore, the engineer is determining the capacity of his sewers he must have reference (1) to the maximum outflow, (2) to the amount of subsoil water which may be accidentally or designedly admitted, and which is a constant and an almost invariable quantity, and (3) to the maximum quantity of surface waters which may be admitted at periods of rainfall, and which, as already shown, will be very great at times of heavy downfalls, even though every pains be taken to reduce as far as reasonable the area of contribution.

The variation in the outflow from sewers to which I have referred is shown in the following particulars which I have obtained of the hourly gaugings of the discharge from the sewers of several towns.*

Hour of Gauging.	Cubic Feet, per Hour.						
	London.		Glasgow.	Wolverhampton (Barnhurst Farm Outfall).	Merthyr Tydfil (Main Outfall).	Leamington Spa (Main Sewer).	Nottingham (Beck Outfall Sewer.)
	East End. Ratcliffe Cross Sewer.	West End. Counters Creek Sewer.					
6 a.m.	20,835	7,290*	2640	6,669·00*	5432·4	2938·80*	6,180
7	23,460	10,875	1709*	6.669·00*	5736·6	2938·80*	7,560
8	35,190	17,100	4848	8,737·20	5736·6	3337·20	11,340
9	49,995	20,835	6106†	9,428·40	6078·6	3735·60	12,180
10	61,365	22,500	6106†	11,842·20	6078·6	4531·80†	12 600
11	63,750	25,635†	6106†	11,842·20	6078·6	4531·80†	13,860†
12	65,715†	20,295	4848	11,842·20	6078·6	4531·80†	13,020
1 p.m.	62,835	18,075	5462	13,456·80†	6078·6	4531·80†	12,600
2	62,250	15,825	4848	11,842·20	6078·6	4531·80†	13,020
3	56,115	16,230	4237	10.233·00	6391·8†	4531·80†	12,180
4	57,165	14,805	4848	11,037·60	6391·8†	4531·80†	12.180
5	53 385	17,040	4237	11,842·20	6391·8†	4531·80†	12,180
6	43,995	17,925	4848	12,652·20	6391·8†	4531·80†	11,340
7	36,870	17,010	3686	11,842·20	6078·6	4133·40	10,140
8	28,875	17,475	3686	10,233·00	5736·6	4531·80†	9,780
9	24,735	16,260	2640	11,037·60	5736·6	3735·60	8,640
10	22,410	13,635	2640	11,842·20	6078·6	3337·20	7,560
11	20,910	11,445	2640	10,233·00	6078·6	3337·20	6,540
12	20,115	10,590	2640	10,233·00	6078·6	2938·80*	6,540
1 a.m.	19,395	9,360	2640	9,428·40	5106·6	2938·80*	6,180
2	18,990	8,520	2640	11,037·60	4815·0*	2938·80*	5,520
3	18,975*	8,280	2640	8,051·40	4815·0*	2938·80*	5,520
4	19,290	8,205	2160	7,360.20	4815·0*	2938·80*	5,220
5	19,290	8,040	2640	6,669·00*	5432·4	2938·80*	4,680*
Time of maximum flow.	a.m. p.m. 10 to 5	a.m. p.m. 9 to 1	a.m. p.m. 8 to 6	a.m. p.m. 10 to 12	a.m. p.m. 9 to 7 and p.m. p.m. 10 to 12	a.m. p.m. 10 to 8	a.m. p.m. 8 to 6
Time of minimum flow.	p.m. a.m. 9 to 7	p.m. a.m. 11 to 7	p.m. a.m. 9 to 7	a.m. a.m. 3 to 7	a.m. a.m. 1 to 6	p.m. a.m. 12 to 7	p m. a.m. 11 to 7

* Minimum in the 24 hours. † Maximum in the 24 hours.

* I am indebted to Messrs. Morgan, Harpur, Davidson, and Tarbotton, the town engineers of Wolverhampton, Merthyr Tydfil, Leamington, and Nottingham, for the figures relating to those towns.

LXXVII.—Liquid Sewage to be removed by the Sewers of Towns and Villages. When speaking of the sewage of the dwelling (Section LI.) I gave a definition of the term "sewage," as adopted by the Sewage Committee of the British Association, and declared that the *solid* refuse belonged to the scavenger, and the *liquid* refuse to the sewer. This division applies also to towns and villages. It is a matter of frequent remark, however, that many solid materials are admitted into the sewers, and carried down by them to the outfall, which belong to the scavenger and never ought to have entered them. The collection and removal of such solid materials will nevertheless form no part of the scavenger's duty. They must be the object of special treatment at the sewer mouth. They must be screened out of the sewage, and dealt with separately from the smaller particles, which float on through any grating used as a screen. It must in fact be considered the province of the engineer to deal with all the materials, solid as well as liquid, which have once entered the sewers. (See Section XCIII.)

I will now address myself to the works necessary for the removal of liquid refuse by the sewers of towns and villages, and afterwards speak of the scavenger's treatment of that portion of the solid refuse which does not enter the sewers at all.

SEWERAGE OF THE TOWN AND THE VILLAGE.

LXXVIII.—General Arrangement of Sewers or System of Sewerage. All common sewers constituting the sewerage system of a district, should be laid in straight lines wherever their sizes are not sufficient to allow of the passage of a man up them to remove deposited matter.

All sewers should have true and even gradients from point to point, and where curves are unavoidable an extra fall should be given to compensate for increased friction.

In the streets of a town the sewers should if possible be laid in the centre, so as to be equally accessible for private junctions from both sides.

At the junction of one common sewer with another—and in the case of small sewers at every change of direction and every change of gradient—there should be a shaft in the form of either a manhole or a lamphole which may be used for the several purposes of ventilation, flushing, inspection, and removal of obstructions. (See Drawings III. and XX.)

Where sewers are of large size and allow of a man working freely in them—thus reducing the advantage of straightness of course—or where from local circumstances it is desirable to effect the junction of two or three sewers at one point without the introduction of a manhole, the junction should be made by curves in the direction of the flow of the main sewer. Drawing XV. shows a junction of this character in brickwork adopted by Mr. Tarbotton, C.E., of Nottingham, and Figs. 85 and 86 show pipe junctions of a similar form.

FIG. 85.

FIG. 86.

Manholes consist—as their name implies—of shafts, down which a man may descend to the level of the sewers. They should, if possible, be placed at the junction of one common sewer with another, and at the concentration of several sewers, the straight course of each being continued into it. They should, as already stated, be constructed also at angle points, and at intervals which will best serve to bring the whole sewerage system under perfect control, both as regards its examination and its cleansing, and so avoid the necessity of breaking up the street or ground in which the sewers are laid whenever an obstruction occurs. The bottoms of all manholes should be so devised that the sewage should flow readily through them from inlet to outlet. This is done by forming in the bottom a grooved course or channel, which serves the purpose of a curved junction pipe.

The advantage of the existence of manholes in the positions I have indicated will be manifest when it is remembered that from them a man can examine the action of the several sewers in the different directions which they take as well as carry out the work of flushing or removing of obstacles (see Section LXXXV.) This will be the more apparent after an examination of the system of sewers shown on Drawings III. and XX. and a study of the "Suggestions"

issued by the Local Government Board, which were drawn up by Mr. Rawlinson, to whom is due the merit of many arrangements which now are approved and adopted by all engineers.

Lampholes—as their name implies—consist of a shaft down which a lamp can be readily lowered to the level of the sewer in order that the man at the next manhole may see whether any obstruction exists in the length of sewer running from the one to the other. If obstructions are found and flushing will not remove them, recourse will have to be had to rods, jointed in a way similar to chimney-sweeping tools, which will effect the removal without difficulty. They will extend to a distance of several hundred feet. Lampholes also serve as watch-holes by which the flow of sewage through the sewers may be observed.

The manholes and lampholes should not only serve to effect the several objects to which I have referred, but to secure also by their united action the perfect ventilation and aëration of the whole sewerage system. Where they are sufficiently numerous and are placed in proper positions, not only may the passage of sewer gas from the common sewers into houses be prevented, but, by the even ventilation afforded, excessive odour in the streets may be obviated also.

Where, owing to local features, manholes exist at points sufficiently near each other to afford in themselves facilities for effecting the duties enumerated, lampholes are not essential. It is not consistent with practice to lay down any rule as to distance between sewer shafts, but it must not be too great to prevent the uniform aëration of which I have spoken. Speaking approximately, the distance from one shaft to another should not exceed a hundred yards; but it is better to have too many than too few.

Considerable care is requisite when effecting the junction of lateral sewers with main sewers, either by manholes or by curves, to deliver the tributary sewage at such a height and in such a manner as not to interfere with the perfect flow of the contents of the main sewer. Upon this point Mr. Rawlinson lays down the following excellent rules* in which I thoroughly concur.

"Sewers of unequal sectional diameters should not join with level inverts, but the lesser or tributary sewer should have a fall into the main at least equal to the difference in the sectional diameter. . . . If the inverts of tributary sewers are not above, or at the least are not on

* Suggestions as to the Preparation of Plans for Sewerage and Water Supply—issued by the Local Government Board.

the level of the ordinary flow of sewage in the main sewer, such tributary sewers or drains" (private communicating sewers) " will be liable to be back-watered, in which case deposit will take place in the length of submerged invert, and so the tributary sewer or drain" (private communicating sewer) "will become choked with its own silt. Many drains" (private communicating sewers) "are so choked where all the inverts in a flat district join upon the same level, because the sewage of the main sewer, which is in some degree constant, back-waters the inverts of the tributaries as described, which tributaries are only in use intermittently."

Where a large branch sewer joins the main sewer in a manhole at a higher level, the union may be favourably effected in the manner designed by Mr. White, of Oxford. The fall is broken and the disturbance lessened by several steps, the materials of which are of blue Staffordshire pressed bricks, the nosings of the steps being purposely formed in a rounded shape. The tread of each step has a fall forward of half an inch, and also a cross fall to its centre of half an inch to prevent any lodgment of solid matter.

Mr. Rawlinson further says:

"Earthenware pipes of equal diameters should not be laid as branches or tributaries, that is 9 in. leading into 9 in., or 6 in. into 6 in.; but a lesser pipe should be joined on to the greater, as 12 in. to 15 in., 9 in. to 12 in., 6 in. to 9 in., and so on.

" Side junctions for house drains" (private communicating sewers) "should be provided in all new sewers and drains. The position should be sketched and indicated by figures in a book, or on a plan. Side junctions not used at once should be carefully closed for subsequent use. If side junctions are not provided and put in as the sewers are being constructed or laid, the cost of subsequent provision and insertion will be much greater. It will be cheaper to insert extra side junctions during construction rather than to have pipes to remove or brick sewers to cut after the trenches have been filled in and become consolidated and the road or street surfaces made good."

When devising a scheme of sewerage, it is desirable in flat districts to connect the common sewers one with another in order to gain a more complete circulation of air. This can frequently be effected without any appreciable extra expense.

No general system of sewerage can be perfectly laid out, where pumping is resorted to, without considering and determining beforehand how far the outfall sewer may, without injury, be made serviceable for holding the sewage for a certain period of the day, or during the night, when it may be economical and otherwise desirable to

cease from pumping. Upon this point, however, I shall have more to say when dealing with seaboard towns (see Section LXXX.), and with outfall and intercepting sewers. (Section LXXXI.)

In all instances where a subsoil drain, in association with the sewer, is necessary to reduce the height of the water in the ground, care should be taken that the former is not only deep enough to render the cellar floors dry, but to keep the foundations of dwellings dry also. It is not possible, having regard to economy, to lay down any positive rule in this particular, though the mean depths to be aimed at may be taken to be 10 feet in towns and suburbs, and 8 feet in rural villages.

The engineer when designing the sewers of a district will do well to bear in mind the 23rd section of the Public Health Act, which practically requires the sanitary authorities to take their common sewers within 100 feet of the site of every house which they ought to include within their sewerage system.

The proper provision of gullies to collect the surface waters of streets, roads, and yards—when admitted into the sewers—is also a point of great importance, and must have the particular attention of the engineer.

It is hardly necessary after what I have said as to "back sewerage" (see Section LVIII.), to lay any stress upon it here. I am content to repeat that no sewers should pass under dwellings, and that therefore back sewerage, where dwellings are closely packed, is desirable wherever it can be effected. So essential is it however to avoid any arrangement which necessitates intrusion upon private property—which is inevitable where back sewerage is carried out—that engineers should so arrange and lay out the private communicating sewers as to reduce to a minimum the length of any back sewer serving for combined use.

Where back sewerage is adopted, special pains should be taken to effect automatic flushing by the introduction of flush tanks (see Section LIX.), which are useful in times of rainfall in collecting and utilising the water from the back roofs of houses, but this must be so arranged as to be free from the objection of using down pipes as ventilators.

In joining each private communicating sewer with the common sewer, neither manhole nor chamber is necessary, but the junction should be effected by a curve in the direction of the flow. A light flap, if practicable (see Sections LVIII. and LXXXV.), may be affixed to the junction-eye in brick sewers.

As suggested by Mr. Rawlinson, an important desideratum is the

possession by the sanitary authority of a perfect record in the shape of plans and sections of the whole sewerage system, showing not only the common sewers and each ventilating shaft, but distinguishing which shafts are manholes and which lampholes, and indicating the position of each communicating sewer and junction-eye. Though the necessity of this is manifest to every intelligent mind, it is striking to observe that the Legislature has been content with authorising sanitary authorities "*if they think fit*," to provide a map and keep it at their office. The effect of leaving it optional is —as might have been anticipated—that in very few cases has this all-important point been attended to, and that the majority of districts are therefore without any complete plan of the works which have been executed.

LXXIX.—Mode of disposing of Liquid Refuse of Towns and Villages to be determined before fixing the Course and Position of the Main Outfall or Intercepting Sewers. That the mode of disposing of the liquid sewage of towns and villages must be determined before the course of the outfall or intercepting sewer is finally decided, will become apparent when the following points are recognised, viz.:

1st. That the liquid refuse must ultimately be discharged either into the sea or into a tidal river or estuary, or into an inland river or watercourse forming the natural outfall of the district; and

2nd. That although there may be considerable variation in the direction of the internal sewers in consequence of internal undulations of surface, the prevailing inclination will be towards one or other of the points of ultimate discharge.

These being the ruling conditions, it follows that any treatment of the sewage to free it from "all foul and noxious matters" must be resorted to at some intermediate point between the ultimate outfall and the point at which the main bulk of the sewage is concentrated.

The remaining questions which will determine the precise locality where the necessary cleansing operations shall be carried out, are (1) the existence of a site free from objection on the score of nuisance, (2) the power of reaching such site wholly by gravitation, or partly by gravitation and partly by pumping, and (3) the expediency or necessity of taking the whole of the sewage to a level lower than the site upon which it will be cleansed, and then lifting it to such site. A subordinate, but still an important consideration

will have an influence in determining this question, and that is, the price which must be paid to obtain the site.

With these points determined, the direction of the outfall or intercepting sewer will follow as a matter of course.

LXXX.—On the Classification of Towns and Villages, and the Disposal of their Sewage according to the Nature of the Outfall. All towns in this country may be placed in one of the three classes referred to in the preceding section—(1) towns on the seaboard, (2) towns on estuaries and tidal rivers, and (3) towns on inland rivers and tributary streams. I will deal with them under these heads and add a few special remarks upon (4) the disposal of sewage from villages and hamlets.

(1.) *Seaboard Towns.*—I recognise in the economy of discharging sewage directly into the sea, in the case of towns situated on the seaboard, a good and sufficient reason for the adoption of the plan wherever it can be done without injuriously affecting the shore. The probability is, however, that the floating matters will return, and that the soluble matter will mix with the sea so as to pollute the shores, and in sea-bathing towns such a result should not be possible. The possibility of discharging sewage into the sea unobjectionably only exists where the shore is not used for bathing or for recreation, and where the town does not extend down to the water's edge. Where the town stands well above the sea level, and the outfall sewer may be carried far into the sea without converting such sewer into a sewage-reservoir, the arrangement may be effected.

In cases where the sewage is impounded within the outfall sewer for a period of time during each tide, not only is the sea shore affected in a manner to prejudice the interests of a sea-bathing town, but the inhabitants are injuriously affected by the generation and evolution of gases from the impounded sewage which find their way by the communicating sewers into the houses, and by the gullies and gratings into the streets during the time the sewer mouth is closed. Brighton may be taken as an illustration of this state of things. A visitor standing on the cliff at the ebb of the tide may see the sewage pouring from the outlet and marking its own passage through the sea for a considerable distance, and if he takes a drive on the Parade while the sewage is impounded, he may smell it to his utter disgust. If an engineer desires to study what to avoid and to see works which have been admirably carried out in themselves, he should visit the sewage disposal works of Brighton. Sooner or later there will be provided for the sewage of this important me-

tropolitan watering-place a constant means of discharge by the application of steam power to raise and dispose of it above tidal influence. While the average death-rate of healthy districts is 17 per 1000, that of Brighton frequently rises above 20, and this excess is only to be explained by the character of its sewerage, the treatment of the sewage, and the overcrowding of dwellings, for the town possesses all the advantages due to a southern aspect, an open sea, and a wide reach of downs to shelter it from cold wind, and to afford the means of healthful exercise.

At Liverpool the same retention of sewage in the sewers at high tide exists—and in spite of the fact that the plan of ventilation adopted embraces extraordinary efforts for the extraction of the sewer gases by specially arranged shafts which are carried up the outsides of houses and buildings, and that there are numerous openings in the streets to afford every facility for the escape of such gases, the death-rate reaches 27·5 per 1000. While referring to Liverpool, I would recall your attention to the words of Dr. Duncan (see Section XLVI.) as to the bad condition of the cellar population of that town, which, if not directly caused by the retention of the sewage in the sewers of the low portion of the town must in some measure be increased by it. At Liverpool the discharge of the sewers amounts to double the total water supply of the town, showing in a very marked way that the sewers are not water-tight, and that, consequently, the impounded sewage may, and undoubtedly does, find its way into the soil surrounding the sewers each time the tide rises above the outfall.

It will have been anticipated from my remarks that, even in seaboard towns, the sewage, before it is discharged, should not only be clarified, but that everything should be done within reasonable limits to secure a constant outflow independently of the tide. I hope, too, I have said enough to convey to you my conviction that the ventilation of tide-locked sewers is pre-eminently important, and of more consequence in fact than that of ordinary sewers in inland towns.

One or other of the tried chemical precipitation processes will effect the required clarification of the sewage of this class of towns where land cannot be obtained. With these processes I shall presently deal (see Section XCV.)

(2.) *Towns discharging into Tidal Rivers and Estuaries.*—A considerable number of towns in this country are situated on the shores of tidal waters, some of which reach far inland. The

difficulty of satisfactorily dealing with sewage which can only be carried to the sea by the ebb of the tide, is very considerable.

The banks or shores of these waters generally consist of mud, and are exposed to the atmosphere for a sufficient time during each tide to give off in extremely hot weather an intolerable stench, which is necessarily made worse by mixture with sewage. In dealing with towns on tidal rivers it becomes the duty of the engineer to treat the liquid refuse differently from the way in which he would dispose of the sewage of either a town directly on the seaboard, or one situated on an inland river.

The most rational view of the matter is that while the sewage discharged from seaboard towns directly into the sea may be simply clarified, that which is discharged into tidal rivers, the waters of which are never utilised as sources of potable waters, should be cleansed of its putrescible matters up to a certain standard, which though less stringent than that applied to inland rivers, shall be sufficiently high to prevent its causing the nuisance of which I have spoken.

The standards recognised by the Conservators of the River Thames, as applicable to districts below the intakes of the London water companies, may be adopted for this class of towns. They say of the defecated water to be discharged from these districts:—"1. It should be free from an offensive odour. 2. It should be free from suspended matters, or, in other words, be perfectly clear. 3. It should not be alkaline to turmeric-paper, nor acid to litmus-paper. 4. It should not contain per gallon more than 60 grains of solid matter dried at 260 deg. Fahr. 5. It should not contain more than three-quarters of a grain of organic and ammoniacal nitrogen per gallon. 6. It should not contain more than two grains of organic carbon per gallon. 7. It should contain not less than one cubic inch of free oxygen in a gallon." It should be observed, however, that one of the eminent chemists who signed this recommended standard, Dr. Frankland, —himself a member of the Rivers Pollution Commission,—added these words: "The conditions under which fluid which has been contaminated with sewage may be admitted into the Thames, as prescribed in the foregoing report, will, I have every reason to believe, preserve the river from being offensive to the inhabitants upon its banks; but, whilst thus far agreeing with my colleagues, I wish it to be distinctly understood that, in my opinion, such fluid can only be safely admissible into the Thames on condition that the water is not afterwards used for domestic purposes."

These standards—which, as the Government do not recognise them, are only now useful as indicating the very reasonable view taken by the Thames Conservancy Board—can, it is declared, be reached by several of the chemical processes which I shall hereafter explain. I am of opinion, however, that in the case of tidal rivers which reach far into the country, and the banks of which are exposed at every tide and give off effluvia of increased offensiveness when the tidal water is mixed with sewage, it is not only desirable in many instances to separate the solid matters and clarify the liquid as chemical precipitation will suffice to do, but to purify it also.

How far the Act of this session may affect towns on tidal rivers remains to be seen. In Part II., section 3, it is laid down that "every person who causes to fall or flow, or knowingly permits to fall or flow, or to be carried into any *stream* any solid or liquid sewage matter shall (subject as in this Act mentioned) be deemed to have committed an offence against this Act. Where any sewage matter falls or flows, or is carried into any stream along a channel used, constructed, or in process of construction at the date of the passing of this Act for the purpose of conveying such sewage matter, the person causing, or knowingly permitting the sewage matter so to fall or flow, or to be carried, shall not be deemed to have committed an offence against this Act if he shows to the satisfaction of the Court having cognisance of the case that he is using the best practicable and available means to render harmless the sewage matter so falling or flowing, or carried into the stream." In Part IV. of the same Act it is stated that "'*Stream*' includes the sea to such extent and tidal waters to such point, as may, after local inquiry, and on sanitary grounds, be determined by the Local Government Board, by order published in the *London Gazette*. Save, as aforesaid" (the exceptions are the Lee and Thames, which are under special control, and the sea or tidal waters the use of which for the discharge of sewage has been sanctioned by Act of Parliament), "it includes rivers, streams, canals, lakes, and watercourses, other than watercourses at the passing of this Act, mainly used as sewers and emptying directly into the sea, or tidal waters which have not been determined to be streams within the meaning of this Act by such order as aforesaid."

(3.) *Inland Towns.*—It is not only reasonable but positively necessary that considerations altogether different from those ruling in the case of seaboard towns should determine the mode of disposing

of the sewage of inland towns. The effluent water in such cases should indeed be freed of all foul or noxious matter (Public Health Act, 1875, clause 17), without compromise, and the law should be exercised without hesitation.

The influence of the opposition of manufacturers upon the past and present governments has resulted in a temporary respite, and some ground has been lost by temporising which had been previously gained by slow and certain steps; but when saying this it is impossible to evade the conclusion that the perfect and permanent cleansing of sewage will be sooner or later insisted upon by every voice in the country, and by no persons more decidedly than by the manufacturers themselves. The standards suggested by the Rivers Pollution Commissioners, at first adopted, then abandoned by the late Government, and since ignored by the present Government, but which, nevertheless, afford a very good criterion of what may satisfy the future requirements of inland towns, precluded the admission of the following liquids into any stream.

(*a.*) Any liquid containing in suspension more than three parts by weight of dry mineral matter, or one part by weight of dry organic matter in 100,000 parts by weight of the liquid.

(*b.*) Any liquid containing in solution more than two parts by weight of organic carbon, or ·3 part by weight of organic nitrogen in 100,000 parts by weight.

(*c.*) Any liquid which shall exhibit by daylight a distinct colour when a stratum of it one inch deep is placed in a white porcelain or earthenware vessel.

(*d.*) Any liquid which contains in solution, in 100,000 parts by weight, more than two parts by weight of any metal except calcium, magnesium, potassium, and sodium.

(*e.*) Any liquid which, in 100,000 parts by weight, contains, whether in solution or suspension, in chemical combination or otherwise, more than ·05 part by weight of metallic arsenic.

(*f.*) Any liquid which, after acidification with sulphuric acid, contains, in 100,000 parts by weight, more than one part by weight of free chlorine.

(*g.*) Any liquid which contains, in 100,000 parts by weight, more than one part by weight of sulphur, in the condition either of sulphuretted hydrogen or of a soluble sulphuret.

(*h.*) Any liquid possessing an acidity greater than that which is produced by adding two parts by weight of real muriatic acid to 1,000 parts by weight of distilled water.

(*i.*) Any liquid possessing an alkalinity greater than that produced by adding one part by weight of dry caustic soda to 1,000 parts by weight of distilled water.

Where these standards have been reached for a continuance by any single treatment of sewage it has been effected by recourse to land, either by way of wide surface irrigation (Section C.), or intermittent downward filtration (Section CI.) When local circumstances forbid the acquisition of a sufficient area of land for either of these objects, then one of the chemical processes in association with intermittent downward filtration will have the desired effect. By this latter combination a very small area of natural soil, when properly prepared, will perfect that purification which chemical treatment has failed to reach by itself. It may be said that there are places in which no land whatever can be obtained; but as I have never yet seen an instance in which this is the case, I am unable to support the assertion.

(4.) *Villages and Hamlets—their Special Treatment.*—These remarks upon the disposal of the liquid refuse of towns apply equally to villages. It may certainly be assumed that after the scavenger has removed the solid portions of sewage a means must still be provided of disposing of all liquid sewage, come from whence it may.

It has been taken for granted by most persons—simply because the point has not been thoroughly discussed—that if solid refuse is disposed of in some approved manner, very small places may turn their slop water into the nearest watercourse. This impression will have but a transient existence, though the money now being spent in temporising with difficulties and in endeavouring to evade the law is very considerable. I feel bound to assert—though in the present state of the public mind I may not obtain general concurrence—that there is no other way of satisfactorily disposing of the liquid refuse of any community than by a common water-tight sewer which shall collect and discharge it for appropriate treatment. This cannot be too well understood, for the precise mode of disposing of liquid sewage becomes comparatively easy directly it is determined to collect and deliver it at a given point.

In very large towns, such as the Metropolis, Manchester, Sheffield, Birmingham, &c., surrounded as they are by wide-reaching populous suburbs—the difficulty of finding a sufficient area of land where the sewage may be cleansed and freed of its noxious portions

before discharge into rivers, has hitherto been deemed insuperable. With inland towns of medium size the obstacles which have prevailed are gradually vanishing, and the use of land is daily extending with every probability of becoming a successful solution of the question, especially when modified by the adoption of intermittent downward filtration as a means of reducing the area to the limits at command. (See Sections CI. and CII.)

In dealing with villages and hamlets where the population is to be counted by tens instead of by thousands, the difficulty is not in finding land by which to cleanse the sewage, but in organising permanent and effective arrangements. Yet where there exists the will, the way is simple enough. The application of the sewage of a village to land with the aid of some means of collecting the sewage such as the self-acting sewage regulator (see Appendix), appears pre-eminently the right thing when it is remembered that all village communities should possess gardens, and many of them do possess "allotment gardens" set aside for labourers, and that to utilise the liquid sewage on these gardens would be a great boon to every one interested, inasmuch as such a ready means of manuring is precisely that which would be most appreciated by the poor. I commend this suggestion to rural parochial authorities.

LXXXI.—Main Outfall and Intercepting Sewers. Having by investigation arrived at the quantity of sewage to be discharged and its maximum rate of outflow, the extent to which it will be constantly diluted by subsoil water and occasionally swollen by surface waters, and the provision to be made in the sewers for the liquid refuse of trade—and having moreover determined the mode of disposing of the sewage—the engineer can at once proceed to decide the details of his scheme of operations.

The size of the main sewer will be greatly governed by the mode adopted for "intercepting" the sewage. The term "intercepting" is as often applied to a principal sewer cutting off existing sewers which discharge into a river at low level, as it is to a sewer collecting and delivering the sewage of a higher district by gravitation simply. Both intercept the sewage, but practically the term is more properly applied to the latter, *i.e.*, the sewer which divides the high ground from the low, and keeps the sewage which may be discharged by gravitation from reaching the lower parts of a town. Where it is possible to effect this separation, it is often a desirable thing to do, as by thus increasing as much as

possible the outflow by gravitation the quantity that must be lifted is reduced to a minimum.

An intercepting high-level sewer is often found to be the best conduit for discharging the sewage of low-level districts. This is effected by collecting the sewage of the latter at a point most eligible for the purpose, and pumping it up to the high-level intercepting sewer. The whole of the sewage of the town may then be delivered advantageously at one point. No better illustration of the advantage of separating the sewage of the higher from the lower part of a town could be given than that afforded by the metropolis, where the sewage of 27½ square miles on the north side of the Thames is intercepted by high and middle level sewers and taken to the outfall at Barking by simple gravitation, the sewage of the low parts, consisting of 25½ square miles, being lifted into the higher level sewer and discharged with the sewage it collects. It does not follow as a matter of course, however, that, in all cases where the levels will admit of separation, such a treatment is the most economical. The instances are not rare in inland districts in which the surface may be so much divided by undulations as to render it less costly to collect the sewage by one low-level sewer, and to lift the whole together, than to divide it into several parts and lift only the sewage of the lower parts.

In seaboard towns where the outfall sewers are tide-locked, every effort should be made, for the reasons already given, to intercept and discharge by gravitation as much sewage as possible and dispose of it free from tidal influence.

It is not an uncommon practice in inland towns, where pumping is resorted to, to convert the main outfall sewer into a reservoir for the collection of the sewage during the night, with a view to reduce the outlay which constant pumping would involve, and the same evil effects which I have stated to be produced in sewers locked by the tide may be produced in towns where this practice is adopted.

It is hardly necessary to say that where such reservoirs do exist every precaution is required to avoid overcharging them with waters which might be intercepted, while, as already stated, it is essential in every case to provide special ventilation for the escape of the gases generated in them during the detention of the sewage. Such collections of sewage in sewers are only to be sanctioned in very special cases, and no rules can be laid down to determine their size and construction, as the conditions will differ in every case.

LXXXII. — Sizes and Velocities required to render Sewers self-cleansing. To determine accurately the size and inclination of the common sewers it may be intended to construct, it is necessary to have reference to the amount of foreign water and solid matter which will be brought into them in addition to the quantity and the character of the sewage-proper. A velocity of 60 feet per minute will be sufficient for the discharge of clear sewage closely approximating the character of water, and sewage strained of its coarser particles will flow without deposit with a velocity of 90 feet per minute. Ordinary sewage, I consider, requires a mean velocity of 150 feet per minute. Wicksteed's experiments showed that a mean velocity of 137½ feet per minute would suffice for the removal of heavy sewage matter when the sewer was running full or half full, though Mr. John Phillips, of the Westminster district, declared that it required a constant velocity of 150 feet per minute to effect the same object. Mr. Robert Stephenson and Mr. Hawksley considered a velocity of two miles per hour, or 176 feet per minute, necessary. Sir Joseph Bazalgette prescribed, I believe, a velocity in large sewers of two miles per hour, or 176 feet per minute, when running three quarters full, 165 feet when running half full, and 146 feet per minute when running one-third full. The Government referees on the main drainage of the metropolis—Messrs. Galton, Simpson, and Blackwell—considered that a *mean* velocity of 150 feet per minute was sufficient to clear the "main channel" which they proposed for the discharge of the sewage of the metropolis, while Messrs. Bidder, Hawksley, and Bazalgette condemned that provision, because at low water the velocity would be reduced to 90 feet per minute. The late Mr. Beardmore laid it down in his "Manual of Hydrology," that the following bottom velocities have the effect stated on the different materials particularised:

Feet.			
30	per minute	will not disturb	clay with sand and stones.
40	,,	will move along	coarse sand.
60	,,	,,	fine gravel, size of peas.
120	,,	,,	rounded pebbles, 1 in. diameter.
180	,,	,,	angular stones, 1¼ in. diameter.

Bottom velocity, which imparts the greater motion, differs from mean velocity in the ratio of from ·75 to ·85—say ·80 to 1—or fourth-fifths. The greatest discharge from a circular conduit is

when it is not quite full—*i.e.*, when rather better than fifteen-sixteenths full, and the greatest velocity occurs when it is thirteen-sixteenths full.

To give a practical illustration of the fall or inclination required to obtain the three velocities of 60 feet per minute, 90 feet per minute, and 150 feet per minute, and to make manifest the value of screening sewage before it is carried forward for distribution or treatment, I may state that a 2 feet sewer, if discharging clear sewage with a velocity of 60 feet per minute, would require a fall of rather more than one foot per mile,—if discharging strained sewage with a velocity of 90 feet per minute, $2\frac{1}{2}$ feet per mile,—and if discharging ordinary unscreened sewage with a velocity of 150 feet per minute, a fall or inclination of $7\frac{1}{2}$ feet per mile.*

The opposite Table will give the velocities of water flowing through and the quantity discharged from circular pipes or culverts per minute when laid at different inclinations, and running half and three quarters full.

This Table is calculated from the following formula which was adopted by the late Mr. Beardmore, and which has been found to be very reliable:

$$V = 55\sqrt{R \times 2H}.$$

R=hydraulic mean depth in feet.
H=fall in feet per mile.
V=velocity in feet per minute.

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* In America a very different view is taken. Mr. Waring, Jun., in his "Sanitary Drainage of Houses and Towns," says:

"Concerning the rate of fall necessary for the removal of ordinary road silt from sewers, Adams gives the following table of inclination for pipes of different sizes *running half full*, based on careful calculations and practical trials with the sewerage works of the City of Brooklyn.

For	6-inch	pipes	a grade of	1 in 60.
"	9-inch	"	"	1 in 90.
"	12-inch	"	"	1 in 200.
"	15-inch	"	"	1 in 250.
"	18-inch	"	"	1 in 300.
"	24-inch	"	"	1 in 400.
"	30-inch	"	"	1 in 500.
"	36-inch	"	"	1 in 600.
"	42-inch	"	"	1 in 700.
"	48-inch	"	"	1 in 800.

When the direction changes, the friction is increased and the fall must be increased to compensate for this. When the lay of the land permits it, the most rapid fall should be given at the upper end of the sewer, where the quantity of water is least, and where the greatest velocity is consequently needed to secure a cleansing flow."

t inclinations, when three-quarters and one-half full.

r Mile, 54.		8 Feet per Mile, 1 in 660.			9 Feet per Mile, 1 in 586.			10 Feet per Mile, 1 in 528.		
scharge.		Vel.	Discharge.		Vel.	Discharge.		Vel.	Discharge.	
ft.	galls.	feet.	cub. ft.	galls.	feet.	cub. ft.	galls.	feet.	cub. ft.	galls.
1·7	216	104·6	37·1	231	110·9	39·4	245	116·9	41·5	258
9·6	122	95·2	21·0	130	101·0	22·3	139	106·5	23·5	146
1·3	444	120·8	76·3	475	127·8	80·7	502	135·0	85·3	531
0·4	251	110·0	43·1	268	116·6	45·8	285	122·9	48·2	300
4	772	135·0	133	828	143·2	141	878	151·0	149	928
0·5	439	122·9	75·4	469	130·4	80	498	137·5	84	523
6	1,221	147·9	210	1,308	156·9	223	1,389	165·4	235	1,464
1	691	134·7	119	741	142·8	126	785	150·6	133	828
9	1,801	159·8	309	1,925	169·5	328	2,144	178·6	345	2,150
3	1,015	145·5	174	1,084	154.3	185	1,153	162·6	195	1,215
4	2,517	170·8	431	2,686	181·2	458	2,854	191·0	482	3,003
8	1,420	155·5	244	1,520	165·0	259	1,614	173·9	273	1,701
2	3,377	181·2	579	3,608	192·2	614	3,826	202·6	648	4,038
6	1,907	165·0	328	2,044	175·0	347	2,162	184·4	366	2,281
0	4,393	191·0	754	4,699	202·6	802	4,998	213·5	843	5,253
9	2,486	173·9	426	2,654	184·4	452	2,816	194·4	477	2,972
5	5,577	200·3	957	5,964	212·4	1,015	6,325	223·9	1,069	6,662
6	3,153	182·4	541	3,371	193·4	574	3,577	203·9	605	3,770
3	6,936	209·2	1,189	7,410	221·9	1,262	7,865	233·9	1,330	8,288
9	3,920	190·5	673	4,194	202·0	713	4,443	213·0	752	4,686
9	8,469	217·8	1,453	9,055	231·0	1,541	9,603	243·5	1,625	10,127
9	4,792	198·3	822	5,122	210·3	872	5,434	221·7	918	5,721
6	10,195	226·0	1,749	10,900	239·7	1,855	11,560	252·7	1,955	12,184
5	5,764	205·7	989	6,163	218·2	1,049	6,537	230·0	1,106	6,892
4	12,115	233·9	2,078	12,950	248·1	2,204	13,735	261·5	2,324	14,483
0	6,855	213·0	1,176	7,329	225·9	1,247	7,771	238·1	1,315	8,195
4	14,234	241·6	2,442	15,219	255·7	2,585	16,110	270·1	2,731	17,020
2	8,052	220·0	1,382	8,612	233·3	1,466	9,136	245·9	1,545	9,628
7	19,114	255·7	3,272	20,391	271·8	3,478	21,675	286·5	3,666	22,847
5	10,842	233·3	1,855	11,560	247·5	1,968	12,265	260·8	2,074	12,925
1	24,872	270·1	4,267	26,592	286·5	4,526	48,206	302·0	4,771	29,733
7	14,066	245·9	2,414	15,044	260·8	2,561	15,960	275·0	2,689	16,758
5	89,287	295·9	6,732	41,955	313·8	7,140	44,497	330·8	7,526	46,903
2	22,198	269·4	3,808	23,732	285·7	4,040	25,178	301·2	4,268	26,599
7	57,691	319·6	9,897	61,680	339·0	10,496	65,413	357·3	11,065	68,959
7	32,638	291·0	5,599	34,894	308·6	5,939	37,013	325·3	6,260	39,013
7	80,63	341·7	13,818	86,116	362·4	14,657	91,345	382·0	15,449	96,281
3	45,75	311·1	7,810	48,673	330·0	8,293	51,688	347·8	8,741	54,475

It may be desirable here to give the formulæ of the four different foreign authorities principally recognised in this country by engineers. I do not however consider either of them so reliable as that of Mr. Beardmore which I have adopted in the Table I have given.

Du Buat's formula reduced to English measure:

$$V=\frac{307\ (\sqrt{R}-0{\cdot}1)}{\sqrt{S}-L\ (\sqrt{S}+1{\cdot}6)}-0{\cdot}3\ (\sqrt{R}-0{\cdot}1).$$

V=velocity in inches per second.
R=hydraulic mean depth=¼ diameter in inches.
S=slope or difference of level.
L=hyperbolic logarithm, and found by multiplying the common logarithm by 2·3026.

In the following formulæ English feet are employed.

V being the velocity per second.
D „ diameter
H „ head or pressure } of the pipe.
L „ length

Prony's simple formula.

$$V=48{\cdot}449\sqrt{\frac{D\,H}{L}}.$$

Eytelwein's formula, as given by Tredgold:

$$V=45{\cdot}5\left(\sqrt{\left(\frac{D\,H}{L+47\,D}\right)}\right).$$

Poncelet's formula:

$$V=47{\cdot}95\sqrt{\left(\frac{D\,H}{L+54\,D}\right)}.$$

The quantities given by these formulæ were tested by actual discharges and the results were given at the Institution of Civil Engineers by Mr. Murray, C.E., in the following tabular statement. (See Minutes of Proceedings of the Institution of Civil Engineers, vol. xii. page 55.)

Diameter of Pipe.	Length.	Head or Pressure.	Discharge per Minute.	Calculated Discharge per Minute.	
inches.	feet.	feet.	cubic feet.	cubic feet.	
2·	3,300	12·75	1·617	1·507	Du Buat.
				1·609	Prony.
				1·509	Eytelwein.
				1·59	Poncelet.
4·5	14,930	51·00	11·333	11·252	Du Buat.
				11·491	Prony.
				10·784	Eytelwein.
				11·281	Poncelet.
12·789	3,837	12·90	155·	158·	Du Buat.
				155·	Prony.
				145·	Eytelwein.
				141·	Poncelet.
12·789	14,963	21·582	111·	99·	Du Buat.
				102·	Prony.
				99·	Eytelwein.
				98·	Poncelet.
19·184	5,052	4·929	217·	223·	Du Buat.
				230·	Prony.
				215·	Eytelwein.
				226·	Poncelet.
30·	5,280	9·00	880·	926·	Du Buat.
				932·	Prony.
				865·	Eytelwein.
				910·	Poncelet.

LXXXIII.—Circular and Egg-shaped Sewers compared. An advantage is gained when the quantity of sewage varies from a small minimum to a large maximum by the adoption of egg-shaped sewers in the place of circular ones, the advantage consisting in the shape accommodating itself to the fluctuation of the flow. When the quantity is small the lesser diameter of the invert of the egg-shaped sewer affords a better scouring power than the larger diameter of an equivalent circular sewer, while the increased size of the upper part of the former conduit affords the requisite space for an increasing outflow.

In cases, however, where the sewage maintains a minimum flow equal to half the maximum flow so that the conduit is never less than half full, there is no advantage in an egg-shaped sewer over a circular one, while the latter is cheaper to construct and of greater strength.

The best form of an egg-shaped sewer is stated to be that given in Mr. Baldwin Latham's excellent work on Sanitary Engineering (p. 101). In this form the horizontal diameter is two-thirds of the vertical height, the radius describing the invert being one-fourth the horizontal diameter. The semicircle drawn on the horizontal diameter becomes the upper portion of the sewer,

while the segment drawn on the radius forms the invert. By continuing the horizontal diameter half its length on each side, points are gained from which an arc may be struck for the sides to perfect the egg-shaped form. (See Drawing I., Fig. 3.) Mr. Hawksley adopts an egg-shaped sewer of his own form (see Drawing I., Fig. 3), which is very symmetrical, and in which instead of the vertical depth being to the horizontal diameter as 3 to 2 the proportions are as 5 to 4. To ascertain the horizontal diameter by which to construct an egg-shaped sewer equal in capacity to a circular sewer of any given size, Mr. Hawksley says, "Deduct its ninth part, and the remainder is the horizontal diameter of an equivalent oval sewer."

Thus, taking a 3 feet circular sewer as an instance, the horizontal diameter of an oval sewer of the same capacity will be 32 inches, while the vertical depth, which should be as 5 to 4 of the horizontal diameter, will be 40 inches.

I give here a Table showing the sizes, circumferences, and sectional areas of circular and egg-shaped sewers.

TABLE showing the Circumference and Sectional Area of Circular and Egg-shaped Sewers of different Sizes.

Circular Sewers. — Diameter.	Egg-shaped Sewer.		Circumference.	Sectional Area.	Circular Sewers. — Diameter.	Egg-shaped Sewer.		Circumference.	Sectional Area.
	Depth.	Width.				Depth.	Width.		
ft. in.	ft. in.	ft. in.	ft. dec	ft. dec.	ft. in.	ft. in.	ft. in.	ft. dec.	ft. dec.
1 9	...	...	5·497	2·405		5 9	3 10	15·351	17·311
2 0	...	...	6·283	3·141		6 0	4 0	16·019	18·849
2 3	...	...	7·068	3·976	5 0	...	...	15·708	19·635
	3 0	2 0	8·009	4·712		6 3	4 2	16·686	20·453
2 6	...	...	7·854	4·908		6 6	4 4	17·354	22 122
	3 3	2 2	8·677	5·530	5 6	...	...	17.278	23·758
2 9	...	...	8·639	5·939		6 9	4 6	18·021	23·856
	3 6	2 4	9·344	6·414		7 0	4 8	18·689	25·636
3 0	...	...	9·424	7·068		7 3	4 10	19·356	27·522
	3 9	2 6	10·012	7·363	6 0	...	...	18·849	28·274
	4 0	2 8	10·579	8·377		7 6	5 0	20·024	29·452
	4 3	2 10	11·347	9·457		7 9	5 2	20·691	31·448
3 6	...	...	10·995	9·621	6 6	...	...	20·420	33·183
	4 6	3 0	12·014	10·603		8 0	5 4	21·358	33·510
	4 9	3 2	12·681	11·814		8 3	5 6	22·026	35·637
4 0	...	...	12·566	12·566		8 6	5 8	22·694	37·830
	5 0	3 4	13·349	13·089	7 0	...	...	21·991	38·484
	5 3	3 6	14·016	14·432		8 9	5 10	23·361	40·088
	5 6	3 8	14·684	15·838		9 0	6 0	24·028	42·411
4 6	...	...	14·137	15·904	7 6	...	...	23·562	44·178

On Drawing IX., a number of egg-shaped and circular sewers are given in juxtaposition with some useful data for construction.

LXXXIV.—Construction of Sewers and Materials to be Used. Having spoken somewhat emphatically of the advantage of rendering all sewers water-tight as far as it is possible to do so, it will be my object now to point out the best means by which to arrive at that end. The difficulty, with a limited expenditure and under ordinary conditions, of constructing a perfectly water-tight sewer must be generally admitted, and it is for that reason that great care must be taken to attain that end.

The materials used for sewers consist of (1) bricks laid in cement or hydraulic lime mortar, (2) stoneware pipes, and (3) concrete, used separately, or in conjunction with bricks and pipes. Iron (4) also is used where the sewer has to be taken through unsound ground, under rivers, and in special cases, through closely inhabited districts.

(1.) *Brick Sewers.*—In the construction of brick sewers it need hardly be said that bricks of the best quality should be used. I do not mean that they should necessarily be radiated bricks, but that they should be well burnt and well shaped, and possess adhesive qualities; for although the pressure of the outer earth upon the sewer may be greater than the internal pressure of the sewage outwards when the sewer is full, it is not the less necessary that the cement or hydraulic lime mortar in which the bricks are laid should adhere to the bricks where a water-tight condition of sewer is a paramount object. Ill-burnt and soft bricks should be most stringently rejected. Rough bricks, even if well-shaped and well-burnt, should not be used for the internal lining of sewers, as the suspended matters of the sewage will cling to them, and ultimately coat them with putrescible substances. The London stock brick forms a very good sample of a suitable brick for sewers. Some engineers prefer the Gault brick, but though it possesses a comparatively smooth surface, and therefore can be advantageously used for the inner lining, its lack of adhesiveness does not recommend it. The blue Staffordshire bricks and fireclay bricks glazed on one edge, form superior inverts, and being very hard, strong, and smooth will resist erosion. They are to be preferred to the glazed invert blocks which have been much recommended by some persons. (See Drawing IX.)

The cement or lime used for the mortar in the building of brick sewers should be selected with great care. The former should be Portland cement weighing from 110 lb. to 112 lb. to the striked bushel, and it should be used in the proportion of one of cement to one of clean washed sand. If lime be used at all, it should be the best hydraulic or blue lias lime. Roman cement, which sets more quickly than Portland cement, may be usefully applied as an inside

Quantità per Yard

Quantità per Yard

rendering. There is nothing connected with the construction of brick sewers of more consequence than the mixing of either cement or lime mortar, and when properly mixed it should be used immediately.

If the sewer is constructed below the ordinary level of subsoil water the utmost care is required to keep the work in hand above water by pumping until the cement or lime has become set.

I would refer you to Drawing IX. for details by which the engineer can readily make his estimate of the cost of sewers of different sizes and characters.

(2.) *Stoneware and Earthenware Pipe Sewers.*—None but the best-formed and best-burnt stone or earthenware pipes ought to be used for sewers of any size. Stoneware pipes are to be preferred to those made of fireclay, though if the latter are well made and well burnt they are very suitable.

The thickness of fireclay pipes should be greater than that of the best stoneware. With the latter the thickness should never be less than one-twelfth of the internal diameter. In the smaller sizes this proportion must be increased. A 4-inch pipe, for instance, should be at least half an inch thick, while a good 18-inch pipe need not be more than 1½-inch thick. The depth of the socket should increase with the diameter of the pipe, nothing less than 1½ inch being sufficient in the smaller pipes, and something more than 2 inches being desirable when the diameter exceeds 12 inches.

In laying both the stoneware and the earthenware pipes the joints should in all cases be caulked with tarred gaskin and laid and finished with cement—or in some cases, clay—in order that they may be water-tight. If the cement or clay cracks—which it may do—the gaskin may preserve the water-tight condition of the joint and is very effective in excluding sand, even if subsoil water should penetrate. Great care is necessary to prevent the pipes moving before the cement has become perfectly set.

Although the preferable joint may be made of tarred gaskin and cement, many engineers consider that if the jointing is carefully performed, puddled clay is all sufficient for the purpose. In my opinion, based on thirty years' experience of clay in every shape,* this material cannot be depended upon. When the soil is either always dry, or at one time comparatively dry and at another wet—and such conditions of soil it should be borne in mind must invariably prevail to some extent in the sites of all towns

* "The Theory of Underdraining." A Lecture before the Royal Agricultural College at Cirencester, by the Author.

—clay is the worst jointing material that can be used. In winter the subsoil water rising in the ground will probably keep the soil surrounding the sewers moist and the clay puddle in a state of expansion, while in summer the reverse condition will prevail,—the subsoil water will then sink from the effects of evaporation, the soil will become dry to the invert of the sewer, and the clay puddle will contract and let the sewage out of the sewer. When once this natural result has been produced all chance of a water-tight condition recurring will be destroyed. If a sewer is jointed with clay puddle at no greater depth than 5 feet from the surface it must inevitably be leaky. I have been recently called in to examine the sewers of a district on the new red sandstone formation, the joints of which were laid in clay at a depth of from 8 to 12 feet below the surface, and I was unable to discover one junction which I could positively declare to be water-tight, while there were several in which I could insert my finger without meeting any clay at all. Doubtless this was bad workmanship, but inasmuch as the strength of any chain is to be measured by its weakest link, so it would happen in any sewerage work where clay was the jointing material, that if two or three joints in a hundred yards were faulty the influx of subsoil water or the efflux of sewage would amount to large totals and frustrate a design which was perhaps very good in other particulars. I should explain that, in the case I refer to, the jointing consisted not of a band of puddle but of merely the insertion of clay in the socket between pipe and pipe, with a shoulder of clay abutting on the flange of the socket. This I believe to be a frequent mode of using clay, and it explains how in certain geological formations the amount of water supply and the quantity of sewage discharged from the sewers, seldom correspond. Moreover, a clay joint readily yields to the pressure of sewage outwards, either from the admission of surface water into the sewer or from the use of water or sewage for flushing. I am now dealing with a case (Hitchin, Herts) where clay puddle was used for the jointing of 18-inch pipes which were laid below the bed of a river and in which there has been seen alternately fountains of diluted sewage rising up through the joints *from* the sewer, and eddies of water passing down from the river through the same vacancies *into* the sewer. At Hitchin, surface waters (which had been *designedly* admitted into the sewer) were the cause of the vagaries which the clay joints could not resist. Under favourable circumstances clay, with gaskin as a core, may form a suitable jointing material, while it will be cheaper than cement and gaskin, but *as a rule*, engineers will do well to hesitate in adopting it.

When laying pipe sewers, to be jointed either with cement or clay, care should be taken to hollow out the bottom of the trench at each joint, so that the full length of the pipe between joint and joint may have a perfect bearing on solid earth. Much depends upon the laying of the pipes in true position. Wherever the size of the pipe will admit of it, a man or boy should be employed inside the pipes as they are being laid, to make good, with some of the best of the jointing material, the *inside* of the joint.

If there is any doubt about the efficiency of tarred gaskin and cement to form a perfect joint, a band of concrete must be resorted to as an additional precaution.

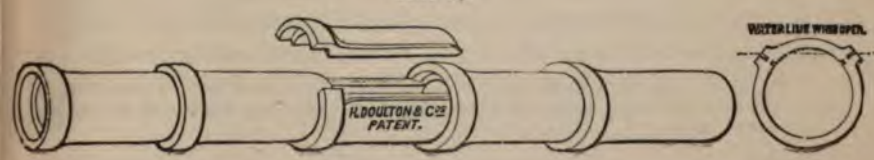
The pipes known as Stanford's patent joint pipes, shown in Fig. 87, are provided with a jointing material which it is intended

FIG. 87.

shall obviate the necessity of using either cement or clay. This material is cast in rings upon the spigot and in the socket of each pipe. The casting is true and smooth, and the custom when laying the pipe is to grease the joints, and by a twist of the pipe to fit them closely together. I have not yet had any great experience of these pipes myself, but I understand that they have been adopted in various places with success.

To provide a means of removing obstructions, and of effecting junctions in pipe sewers aftey they are laid, some engineers recommend the laying of some half pipes with half sockets, similar to Fig. 88, along their course, and in the exceptional cases where clay puddle may be advantageously used they may be in their proper place; but seeing that the halves should conform to the same

FIG. 88.



water-tight condition as the rest of the sewer, it is obvious that the means which must be taken to render them so must to some extent defeat their purpose, as it would be necessary to break the cover each time it had to be opened. But even with this drawback the covers afford a more ready means of effecting new junctions with communicating sewers than would exist without them *if* they are fixed in the proper place.

(3.) *Concrete Sewers.*—My observations as to the quality of lime and cement for use as mortar, and as to the mode of using the mortar in connection with brick sewers, apply with even greater force when used in the form of concrete, which is daily coming into greater use with a higher appreciation of its value. Sewers may be made entirely of concrete, and to Mr. Grant, of the Metropolitan Board of Works, we owe much for his clear exposition of its utility. I have shown on Drawing IX. a sewer constructed of Portland cement concrete with a rendering of Roman cement. It is 6 feet in diameter, and will cost, exclusive of earthwork, side entrances, junctions, &c., about 18s. per lineal foot.

Mr. Grant has tested the strength of concrete of different proportions by experiments, the results of which are given in the following Table compiled by Mr. Latham.*

Proportion of Ballast to Cement.	Compressed Blocks.		Not Compressed Blocks.	
	Set in Air.	Set in Water.	Set in Air.	Set in Water.
	tons per inch.	tons per inch.	tons per inch.	tons per inch.
1 to 1.....	1·055	·933	·833	1·041
2 „ 1.....	1·194	·958	1·069	1·000
3 „ 1.....	·833	·986	·666	·777
4 „ 1.....	·833	·777	·777	·750
5 „ 1.....	·680	·986	·666	·652
6 „ 1.....	·566	·544	·505	·472
7 „ 1.....	·458	·444	·388	·347
8 „ 1.....	·375	·375	·347	·305
9 „ 1.....	·333	·305	·277	·250
10 „ 1.....	·291	·291	·222	·194

On Drawing IX. illustrations are given of sewers formed of a ring of 4½-inch brickwork surrounded by concrete. I prefer this character of sewer to all others. Ballast of a very clean description, and cement of the best quality, well mixed in the proportion of eight of ballast to one of cement and quickly used, will give a very

* The figures show the crushing strain of blocks of Portland cement concrete (weighing 110·56 lbs. per bushel), measuring six inches each way, after they had become set for twelve months.

fair result, though where there is any doubt as to the quality of the constituents the proportions may be advantageously altered to seven or six to one. The composition may also consist of mortar made in the proportion of three of sand to one of good hydraulic lime, mixed with the same bulk of shingle or washed gravel. When prepared it should be rammed into form while in a wet condition, and it is better to use the concrete in too wet rather than in too dry a state.

(4.) *Iron Pipes—River Crossings and Sewer Deflections.*—There will seldom be a sewerage work, however small, in which iron pipes will not be used in some parts of the works, either in crossing under rivers, or from one side of a valley to the other, or in passing through unsound ground or in other special cases. To secure the requisite thickness of iron pipes for any special purpose, it is desirable to make a liberal allowance for possible defects, and all pipes should be tested before use by hydraulic pressure. It has been laid down that the resistance which a pipe offers to the internal pressure tending to burst it, is equal to the cohesive strength of its two sides, and the effective area of pressure is the internal diameter of the pipe, and some very useful data upon this subject are given by Messrs. Byrne and Spon in their "Dictionary of Engineering." They say, "If the tensile strength of cast iron is taken as 15,000 lbs. to the square inch, the thickness of a pipe to be subjected to water pressure will be given by the formula

$$\frac{\cdot 433 \text{ H R}}{15{,}000} = \cdot 0000288 \text{ H R},$$

in which H represents the head of water in feet, and R the radius of the pipe in inches. Substituting the diameter for the radius, the formula becomes ·0000144 H D. A pipe having this thickness is strained up to the bursting point. If we take ten as the factor of safety, we have as the formula giving the requisite thickness in practice, $t = \cdot 000144$ H D. Thus suppose a 10-inch pipe to be subjected to a pressure of 200 feet head; the requisite thickness, as given by the formula, is

$$\cdot 000144 \times 200 \times 10 = \cdot 288 \text{ inch.}"$$

"This is less than the necessary practical thickness, and the least thickness that can be cast will possess an excess of strength in this case. If the head were 400 feet the thickness would be

$$\cdot 000144 \times 400 \times 10 = \cdot 576$$

In this case the specified thickness would be $\frac{5}{8}$ inch. Pipes are usually tested by hydraulic pressure up to twice their working pressure.

"The formula generally used by French engineers is

$$t = \cdot 0016\, n\, d + \cdot 008,$$

in which t = the thickness in fractions of a metre, n = the effective pressure in atmospheres, and d = the diameter of the pipe. The constant quantity ·008 metre is the excess of thickness given to render the pipe capable of bearing a sudden shock. The water pipes of Paris, as well as those of several other large towns of France, were calculated from this formula."

Molesworth's formula for finding the thickness of cast-iron pipes is as follows:

$$t = \cdot 000054\ \mathrm{H}\ d + x,$$

H representing the head of water in feet, d the internal diameter of the pipe in inches, and x a constant quantity equalling ·37 inch for pipes less than 12 inches in diameter, ·5 inch for pipes from 12 to 30 inches, and ·6 inch for pipes from 30 to 50 inches in diameter.

Barlow's rules for thick pipes are given by Mr. Box in his treatise on "Practical Hydraulics" as follows:

$$\mathrm{T} = \frac{\mathrm{R} + \mathrm{P.}}{\mathrm{S} - \mathrm{P.}} \qquad \mathrm{P} = \frac{\mathrm{S} \times \mathrm{T}}{\mathrm{R} + \mathrm{T}} \qquad \mathrm{S} = \frac{(\mathrm{R} + \mathrm{T}) \times \mathrm{P.}}{\mathrm{T.}}$$

S representing the cohesive strength of the metal per square inch,—P the internal pressure per square inch in the same terms as S,—R the radius of the inside of the pipe in inches,—and T the thickness of the metal in inches. For cast iron S is taken at 7·142 tons, or 16,000 pounds per square inch.

For thin pipes—*i.e.*, pipes subject to moderate pressures—Mr. Box gives the following rule:

$$t = \left(\frac{\sqrt{\mathrm{D}}}{10} + \cdot 15\right) + \left(\frac{\mathrm{H} \times \mathrm{D}}{2500}\right);$$

D representing the diameter of the pipe in inches, H the safe head of water in feet, and t the thickness of the metal in inches.

The following Table gives the thickness and safe head of water adopted by the late Mr. Beardmore for cast-iron pipes to which has been added the weight and cost per yard.

Bore.	Thickness.	Safe Head of Water. (Double for Proof).	Weight per Yard (including Proportion of Joints).	Cost per Yard at £6 per Ton.	Cost per Yard at £8 per Ton.	Cost per Yard at £10 per Ton.	Cost per Yard at £12 per Ton.
in.	in.	feet.	cwt. qr. lb.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
3	1/4	1000	0 1 0	0 1 6	0 2 0	0 2 6	0 3 0
	3/8	1500	0 1 14	0 2 3	0 3 0	0 3 9	0 4 6
	1/2	2000	0 2 0	0 3 0	0 4 0	0 5 0	0 6 0
	5/8	2500	0 2 14	0 3 9	0 5 0	0 6 3	0 7 6
4	1/4	744	0 1 9	0 2 6	0 2 8	0 3 3	0 4 0
	3/8	1128	0 1 25	0 2 10	0 3 10	0 4 9	0 5 8
	1/2	1500	0 2 15	0 3 10	0 5 1	0 6 4	0 6 1
	5/8	1872	0 3 5	0 4 9	0 6 4	0 7 11	0 9 5
5	1/4	600	0 1 18	0 2 5	0 3 3	0 4 1	0 4 10
	3/8	900	0 2 11	0 3 7	0 4 10	0 6 0	0 7 3
	1/2	1200	0 3 4	0 4 8	0 6 3	0 7 10	0 9 4
	5/8	1500	1 0 0	0 6 0	0 8 0	0 10 0	0 12 0
6	3/8	750	0 2 22	0 4 2	0 5 7	0 7 0	0 8 6
	1/2	1000	0 3 2	0 4 7	0 6 2	0 7 8	0 9 2
	5/8	1250	1 0 18	0 6 11	0 9 3	0 11 7	0 13 10
	3/4	1500	1 1 18	0 8 5	0 11 3	0 14 1	0 16 10
9	3/8	500	1 0 4	0 6 2	0 8 3	0 10 4	0 12 5
	1/2	666	1 1 12	0 8 2	0 10 10	0 13 7	0 16 3
	5/8	832	1 2 20	0 10 1	0 13 5	0 16 9	1 0 1
	3/4	1000	2 0 4	0 12 3	0 16 3	1 0 4	1 4 5
12	1/4	500	1 3 3	0 10 8	0 14 2	0 17 9	1 1 4
	3/8	625	2 0 23	0 13 3	0 17 8	1 2 1	1 6 6
	1/2	750	2 2 17	0 15 10	1 1 2	1 6 6	1 11 9
	5/8	875	3 0 12	0 18 8	1 4 10	1 11 0	1 17 3
15	1/4	500	2 3 8	0 16 11	1 2 7	1 8 2	1 13 10
	3/8	600	3 1 12	1 0 2	1 6 10	1 13 6	2 0 3
	1/2	700	3 3 19	1 3 6	1 11 4	1 19 3	2 7 1
	1	800	4 1 23	1 6 10	1 15 8	2 4 7	2 13 6
18	1/4	412	3 1 12	1 0 2	1 6 10	1 13 6	2 0 3
	3/8	500	4 0 0	1 4 0	1 12 0	2 0 0	2 8 0
	1/2	588	4 2 16	1 7 10	1 17 2	2 6 5	2 15 9
	1	666	5 0 23	1 11 3	2 1 8	2 12 1	3 2 6
24	1/4	312	4 1 19	1 6 6	1 15 4	2 4 2	2 12 11
	3/8	374	5 1 0	1 11 6	2 2 0	2 12 6	3 3 0
	1/2	400	6 1 0	1 17 6	2 10 0	3 2 6	3 15 0
	1	500	7 0 13	2 2 9	2 16 11	3 11 2	4 5 3
30	3/4	300	6 3 14	2 1 3	2 15 0	3 8 9	4 2 6
	1	400	8 3 24	2 18 10	3 11 9	4 9 8	5 7 7
	1 1/8	450	9 1 16	2 16 4	3 15 2	4 13 11	5 12 9
	1 1/4	500	11 0 7	3 6 4	4 8 6	5 10 7	6 12 9

The following Tables, extracted with the permission of Mr. Box from his admirable treatise on "Practical Hydraulics," will be useful.

TABLE of the Proportions of Joints, &c., for Cast-iron Socket Pipes.

Diameter of Pipe.	Depth of Socket.	Lead Joint.			Laying per Yard, Prime Cost.
		Thickness.	Depth.	Weight.	
inches.	inches.	inches.	inches.	lbs.	s. d.
1½	3	⅛	1½	1·2	0 11
2	3	⅛	1½	1·4	1 0
2½	3½	⅛	1½	1·6	1 1
3	3½	⅛	1¾	2·3	1 2
4	4	5/16	2	4·0	1 3
5	4	5/16	2	5·0	1 5
6	4½	5/16	2¼	6·5	1 7
7	4½	5/16	2¼	7·7	1 10
8	4½	5/16	2¼	8·2	2 1
9	4½	5/16	2¼	10·4	2 6
10	4½	⅜	2½	11·5	3 4
12	4½	⅜	2¾	18·0	4 6

TABLE of the Proportions of Cast-iron Flange Pipes.

Diameter of Pipe.	Diameter of Flange.	Thickness of Flange.	Number of Bolts.	Diameter of Bolts.	Diameter of Circle of Bolts.
inches.	inches.	inches.		inches.	inches.
1½	4½	½	3	⅜	3¼
2	5¼	½	3	7/16	3⅝
2½	6	½	4	7/16	4¼
3	6½	½	4	½	5
4	8	½	4	9/16	6¼
5	9¼	½	4	9/16	7⅛
6	10½	½	6	9/16	8¾
7	12	½	6	⅝	10
8	13¼	½	6	⅝	11¼
9	14½	½	6	⅝	12¼
10	16	1	6	¾	13½
12	18¼	1	6	¾	16

Wrought-iron tubes are very useful for special crossings where a girder form of construction can be adopted, such as, for instance, when crossing rivers where supporting piers would be objectionable.

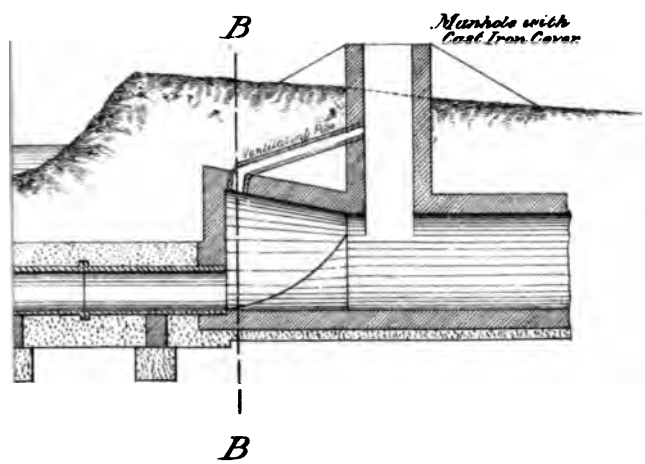
Three illustrations of the way in which rivers may be crossed by iron pipes laid beneath their bed are given in Drawings IX.ᴬ and IX.ᴮ.

Drawing IX.ᴬ illustrates the means which Mr. White, C.E., of Oxford, has adopted for taking a sewer under the Cherwell. The

anitary Engineering: — THE TOWN AND VILLAGE.

Drawing. IX[A]

ee BB.



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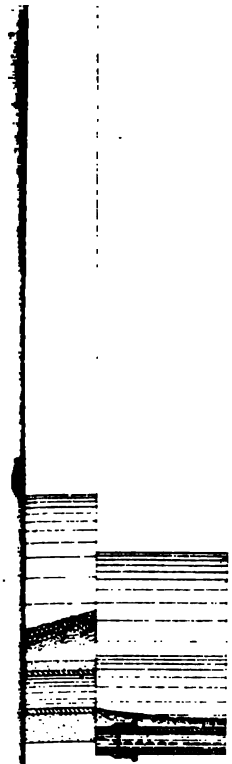

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tube in this case (the form of which is given in section) is supported by brick piers and concrete; the tube being wholly surrounded by concrete in its bed under the river. Between the flanges of the tube vulcanised india-rubber washers three-eighths of an inch thick are placed, and these are screwed together by five-eighths bolts and nuts.

Drawing IX.[B] showst wo other means of crossing under rivers by iron pipes, in the one case by a straight line from chamber to chamber and in the other by a deflection. It will be observed that a chain is placed inside the latter which may at any time be drawn backwards and forwards so as to stir and set in motion any sedimentary substances which might possibly deposit themselves and adhere to the pipes.

There have been objections raised from time to time to the taking of sewage under rivers by inverted syphons or deflected pipes, but they have been advanced more from unfounded prejudice than from positive experience. In many important towns in this and other countries sewage has been taken by these means from one side of a river to the other without difficulty.

I must not quit the subject of this section—the construction of sewers and the materials used in them—without pointing out the fact that in the excavation of trenches and in the driving of adits or tunnels for the laying of sewers through different soils, and in supporting them where the ground is treacherous, the practical experience and ready judgment of the engineer will be tried to the utmost.

I regret that the time at my command will not allow me to do more than make this passing remark.

LXXXV.—Sewer Appliances.

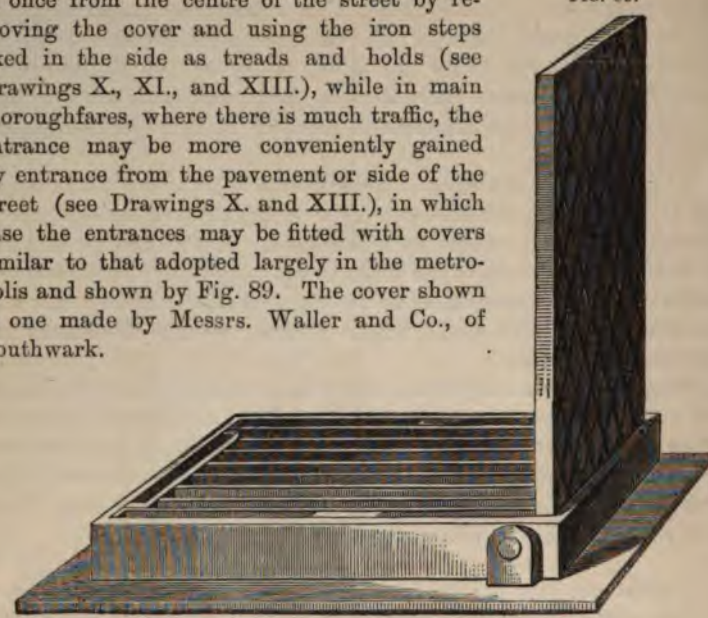
(1.) *Manholes and Lampholes.*—In a previous section (Section LXXVIII.) it was stated that manholes and lampholes at the junctions of common sewers, at the angles of direction, and at changes of gradient, form a fundamental feature in systematic sewerage, inasmuch as they serve the several purposes of flushing, examining, clearing, and ventilating the sewers. There need therefore be little more said as to their utility.

The size, form, and character of manholes vary considerably. In Drawings X., XI., and XIII. will be found some of the most approved designs adopted by the leading engineers of this country.

The mode of entering a manhole is effected in different ways. If it is constructed after the manner of a vertical shaft, it may be entered

at once from the centre of the street by removing the cover and using the iron steps fixed in the side as treads and holds (see Drawings X., XI., and XIII.), while in main thoroughfares, where there is much traffic, the entrance may be more conveniently gained by entrance from the pavement or side of the street (see Drawings X. and XIII.), in which case the entrances may be fitted with covers similar to that adopted largely in the metropolis and shown by Fig. 89. The cover shown is one made by Messrs. Waller and Co., of Southwark.

Fig. 89.



These covers are provided with an inside grating (duplicate lid), which allows of the ventilation of the shaft by the raising of the outer lid without danger to traffic. When manholes are entered directly from the streets the covers should be formed of open gratings to serve constantly as ventilators. In practice the opening in the streets is not found to interfere in any serious way with the public traffic. The covers adopted by me for street and road covers of manholes and lampholes are shown by Fig. 90, and are made by

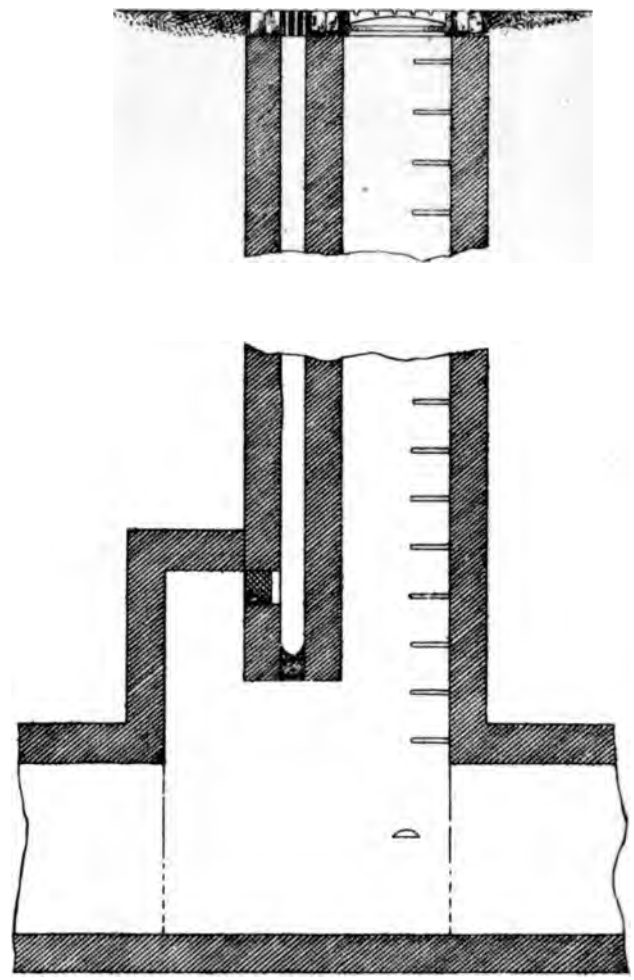
Fig. 90.

Sanitary Engineering; **THE TOWN AND VILLAGE**

Drawing X

Adopted by Mr. Thorburn, C.E.

For Brick Sewers.



Section.

Scale

TOWN AND VILLAGE.

g XI.

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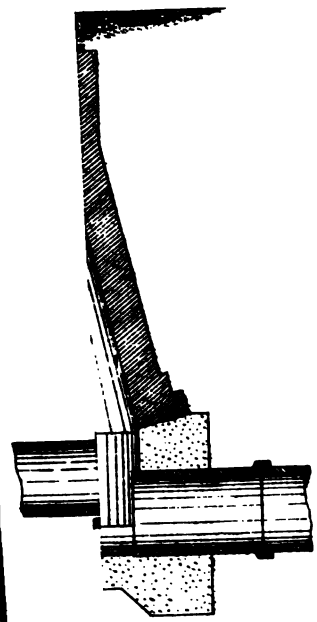

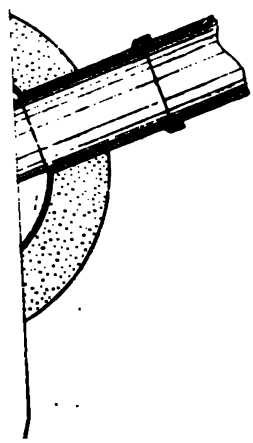

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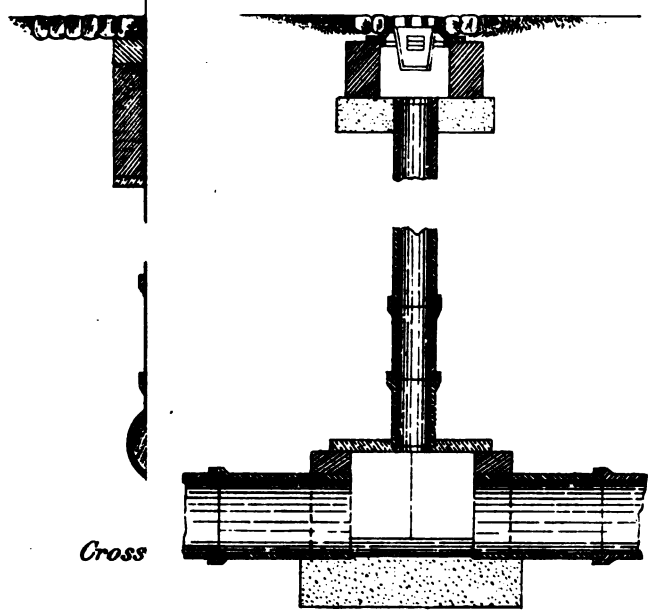
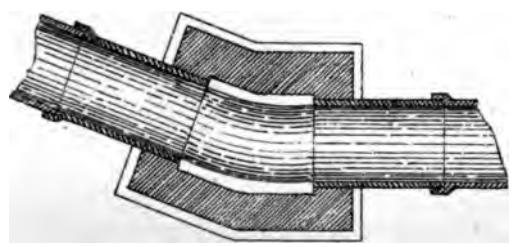
Drawing N.º XII.

Adopted by Messrs. Bailey Denton, Son & North.



Cross

Section.



Plan.

Scale 4 feet

Bailey Denton Son & North.
22 Whitehall Place.

Flood and Co., of New Bridge-street, Blackfriars. Those adapted for manholes are similar in design to, but are larger in size than, those used for lampholes. Where manholes are intended for access to doors or gates fixed in the larger sewers for the purpose of flushing them, the side entrance possesses great advantages over the vertical one, as the mode of construction enables a man very readily to bring the gates or door-valves into action. I shall say a few words on flushing directly.

Below the grating which forms the covering of the manhole there should be a dirt box (see Fig. 90) fixed to intercept the solid matters which find their way through it, and which if allowed to fall to the bottom of the shafts would obstruct the flow of the sewage. The position of the dirt box in the manholes and lampholes is shown on Drawings XI., XII., XIII., as well as in Fig. 90.

The practice of providing ventilating side chambers with gratings in connection with manholes having themselves solid covers, is doubtless a good one, as the dirt falls into the side chamber instead of the manhole. This arrangement is adopted at Liverpool and other places with good effect, and is shown by the designs of Mr. Deacon, Mr. Tarbotton, Mr. Till, Mr. Thorburn, and Mr. Rawlinson. (See Drawings X., XI., and XIII.) The side ventilating chamber, however, is just as liable to be filled with stones and mud from macadamised roads as the dirt box placed in grating-covered manholes, and the engineer will therefore have to balance the respective advantages and disadvantages of each in making a selection. The suspended dirt box which I adopt is less capacious than the chamber referred to, but as it is much more readily emptied no inconvenience is experienced on that account. It may be said to impede ventilation, but if it is formed with a sufficient opening on each of the four sides I do not see that this objection applies.

Two descriptions of lampholes are illustrated on Drawing XII. They generally consist of stoneware pipes of different sizes, placed on end above small chambers built of bricks or concrete in the course of the sewer. Where they are inserted in the course of straight pipe sewers, they may be vertically connected with them by ordinary junction pipes fitting the sewers.

(2.) *Flushing Arrangements and Penstocks.*—There are few systems of sewerage in which the arrangements are such as to render flushing altogether unnecessary. Sewage may be so diluted by foreign water that it may of itself be sufficient to keep the sewers clear, but at the uppermost ends of sewers this favourable condition cannot be attained, and recourse must be had to some additional means of

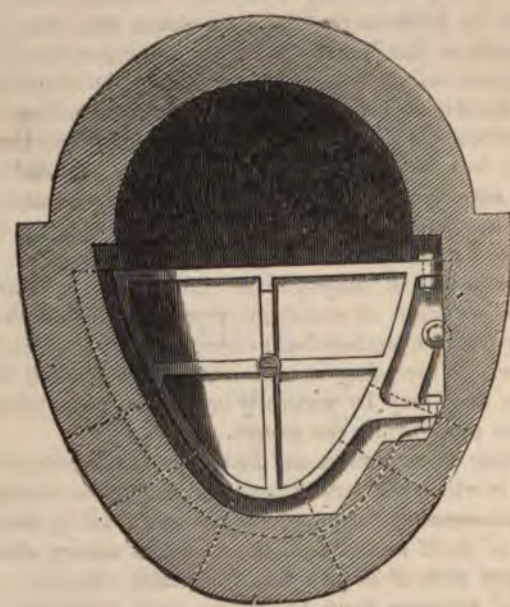
cleansing. At the head of all sewers, in fact, there should not only be an increased fall given to the sewer but some means should be provided of admitting water either from the public water main (in a town), or from a water-cart (in a village), or from a tank built purposely to collect the rainfall and retain it for use in flushing during dry weather.

Where water is scarce it may be made the most of by the use of valves or half gates in the sewers, whereby it may be held back and let suddenly free; thus water or sewage itself in a comparatively small quantity may be made to do good service.

Drawing XIII. shows the arrangements made for flushing in different manholes; in some by means of a swing-gate, as in the case of the manhole of Mr. Till, of Birmingham, or by flap or penstock, as in the design of Mr. Tarbotton, of Nottingham, and in that of my own firm. In smaller sewers in which flaps are used for flushing, the work can be performed from the surface, and the vertical shaft is well suited for the purpose.

A half gate—one made by Messrs. Waller and Co. of Southwark—is also shown by Fig. 91.

Fig. 91.

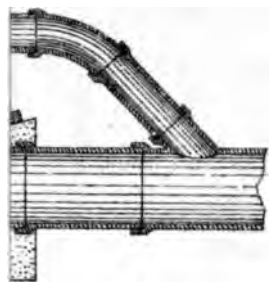


tary Engineering:- **THE TOWN AND VILLAGE.**

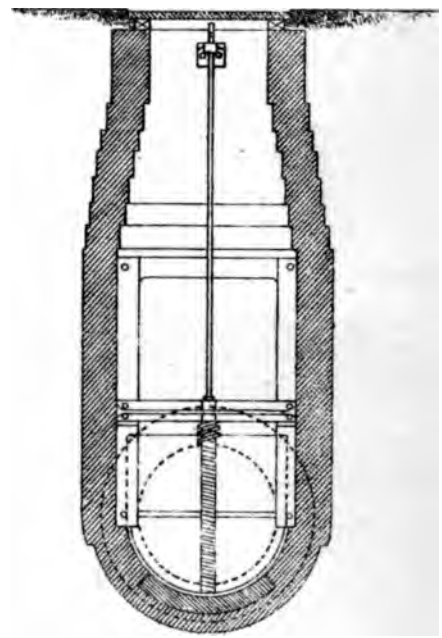
Drawing **XIII.**

Adopted by Messrs. Bailey Denton, Son & North.

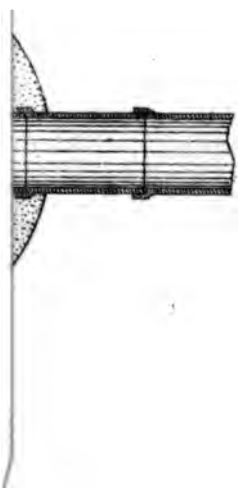
shing Valve.

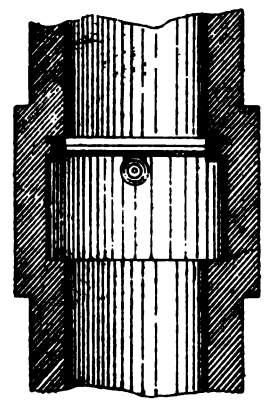


Brick Sewer with Penstock.



Section.





Plan.

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Bailey Denton Son & Nor
22. Whitehall P

Half gates of this kind may be advantageously used in manholes where the sewers are of large size, but with small sewers whole gates or valves are better. Gates should be made to shut *against* the flow and to open with it. Where the sewers are made of pipes a simple flap arranged to open the reverse way—*i.e.*, against the flow—fixed to the outgoing pipe and made capable of being worked by a chain from the top of the manhole, may be made to do a similar duty. (See Drawing XIII.)

Penstocks answer very much the same purpose as flush gates, though the mechanical arrangements by which they are worked are different. The difference consists in the penstock acting vertically, and moving gradually by worm and rack-work in a chamber devoted to the purpose, while the flush gate generally works on hinges horizontally and suddenly.

FIG. 92.

The working of penstocks will be easily understood by an examination of Drawing XIII., and of the detailed illustrations given by Figs. 92, 93, and 94, which show two (Figs. 92 and 93) of Messrs. Waller's, and one (Fig. 94) of Messrs. Stone's penstocks, and which may be taken as illustrative of those now in general use.

The rainfall to be collected from the surface of streets, too, may be utilised, as already mentioned, by securing its collection in a tank placed beneath the side of the road, and constructed on the same principle as the self-acting sewage regulator (Drawing II. Appendix), and Field's flush tank (Fig. 30), the discharge being effected by a self-acting syphon when sufficient water is collected. An arrangement of this kind is shown upon Drawing XIV. by Fig. 5. The detritus from the road is intercepted in one chamber (marked *a* on the drawing referred to), while the water passes

Fig. 93.

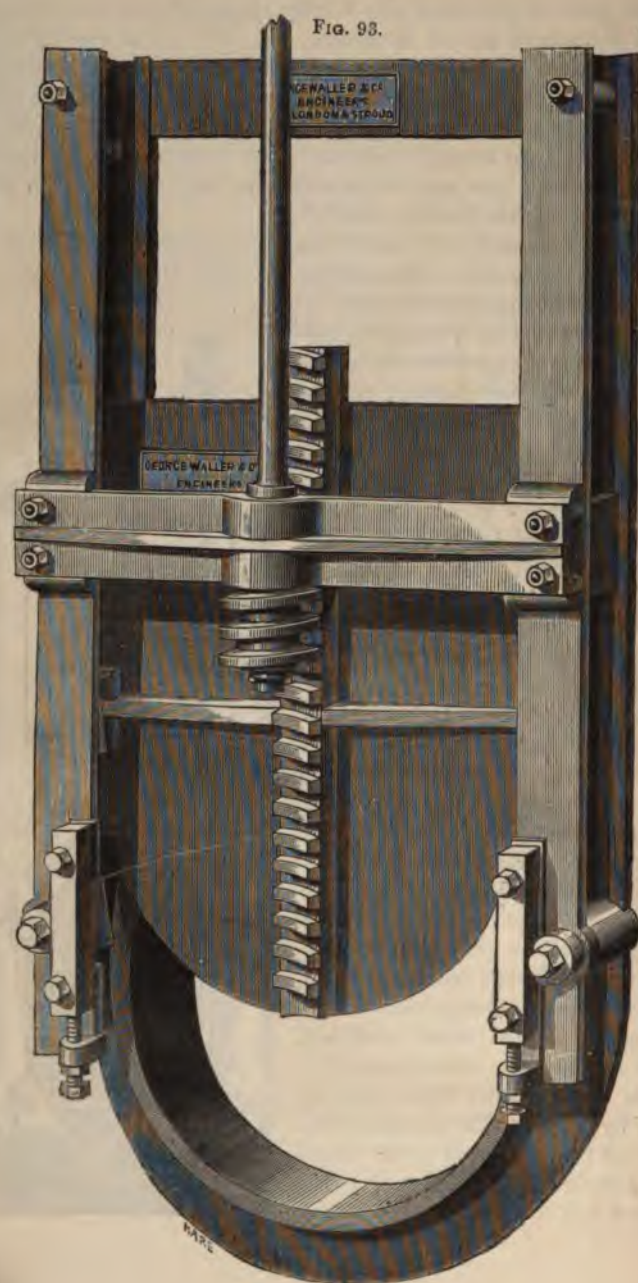
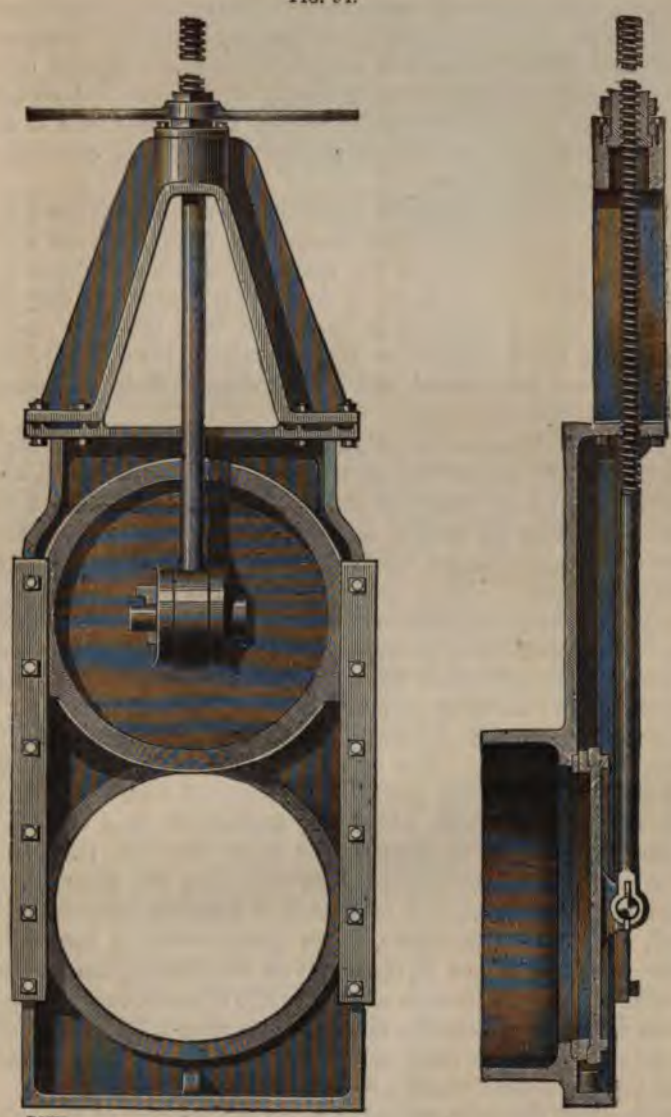


FIG. 94.



through and collects in the other (*b*) until it rises to the crown of the syphon, when it discharges itself, leaving the detritus behind. As the water does not escape until a sufficient quantity to effect the

flushing has risen in the tank to the crown of the syphon, every drop of rain falling on a small contributing surface may be turned to account.

The admission of water into sewers is sometimes effected by a direct connection between the water supply of the town and certain manholes, but this arrangement is wrong, and carries with it an objection which must prevent its general adoption, for water is a rapid absorber of sewer gas.

Where there is a considerable quantity of water at command for flushing, the operation is better commenced from the lower ends of the sewers, but where on the contrary the water is scarce the flushing liquid must be made to do its full amount of duty by detention at several manholes in succession from the head downwards. It is quite possible, as Mr. Rawlinson says in his "Suggestions," to overflush sewers, and disturb them in their beds,—and I will add, to force clay joints.

(3.) *Gullies.*—The provision of gullies, in proper positions, through which the surface waters from streets, roads, pavements, yards, and courts may find their way into the common sewer or pass off by separate drains to the surface streams or watercourses, must also receive careful consideration when designing the sewerage system of a town or village.

The gullies now in use differ in their distinguishing features in two particulars—the one being a comparatively shallow receptacle covered by a grating through which the water and the road detritus pass together into the sewer or surface drain, the other consisting of a catchpit in which the detritus deposits itself while the liquid alone passes onwards. The latter description should be invariably adopted when the gullies are connected with the sewers, for if the solid particles, which are washed off from the roads and streets in times of rainfall, find their way into them, not only do they create obstruction and difficulty, but their subsequent removal after collection is effected at a greatly increased cost. Indeed, Sir Joseph Bazalgette, when giving evidence before the Committee of the House of Commons on the Birmingham Sewage Bill in 1872, went so far as to say that while it would cost only half a crown a yard to remove the detritus when caught by gully catchpits, the removal of the same quantity at the outfall when once admitted into the sewers would involve an outlay of 20s. or 21s.

The depth of the gully-catchpit for the interception of the solid matters will depend upon the nature of the roadway or street, as well as upon the inclination of the surface. For paved streets and regular surfaces, for instance, it will not be necessary to make so great a provision as in cases where the streets are macadamised

and where the inclinations are steep. In the metropolis the sizes of the gullies vary considerably, some of them holding 40 and others as much as 90 cubic feet of deposit. The degree of attention given or rather required to be given by local authorities to the emptying of catchpit-gullies may influence the size of the receptacles, for the more frequently they are emptied the less, of course, need be their capacity. They will generally be larger in rural towns with macadamised roads than in towns with paved streets.

Where gullies connected with sewers exist by the side of footpaths in much frequented streets, and in yards and courts, special care should be taken to prevent the escape of the gases of the sewer, by the most efficient means of trapping. This object is effected in most of the gullies now in use by the common dip arrangement, of which Figs. 95 and 96 are examples; in others by bends or elbows in the pipe connecting them with the sewer; and in others by self-acting balance metal valves. Those gullies in which the water itself is used as a means of trapping are better than those provided with metal balance-valves. The latter are sometimes used where the road detritus and other solid matters are admitted into the sewer. They are subject to derangement by a portion of the solid matter resting on the valve and preventing its closing perfectly, in which case the gases which the valve ought to exclude escape into the street or yard. But even if the valve shuts closely when not in action, directly it is opened by the force of the descending water and its solid matters, the gases that have collected beneath it will rise upwards and escape. The disadvantage of using water as a means of trapping consists in the fact that the water is apt to be evaporated, and it is occasionally necessary to fill the receptacles with water by hose or water-carts.

Fig. 95.

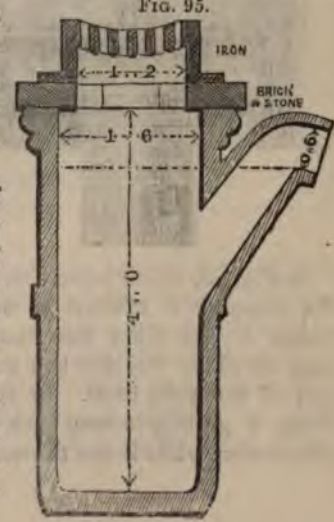


Fig. 95 shows a street gully of the "dip" kind manufactured by Messrs. Doulton. It is made of various sizes, and being of one piece of stoneware is not liable to leakage —a remark which will not always apply to those constructed of brick-work. The level at which the water will be retained above any deposition of solid matter in this gully, and so insure its acting as a trap, is shown by a dotted line.

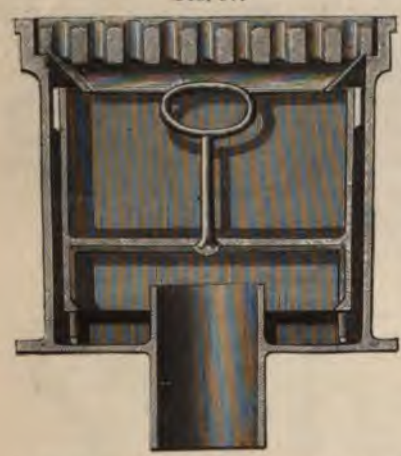
Fig. 96.

Fig. 96 represents another of the dip-trap gullies now in use—Lowe's gully, manufactured by Messrs. Stone and Co., of Deptford. This gully is made of iron, and, as in the last case, the removal of the road detritus and other solid matter collected in it is effected by means of a scoop.

The next two gullies are also of the dip character, but differ from the two just described by containing a moveable receptacle, in which the road dirt is collected, and by which the trapping is effected. These dirt boxes are removed and emptied periodically, and with little labour.

In Fig. 97 the trapping is effected first by the shoot below the grating, which descends a little way into the water retained in the dirt box, and next at the bottom of the outer case, where the mouth of the communicating sewer rises above the level of the lower sides of the dirt box, round which the liquid travels to the sewer. The water forming this latter trap, being protected from the rays of the sun, is not so readily evaporated as it otherwise would be. This gully is manufactured by Messrs. Stone and Co. A somewhat similar gully is made by Sharpe, of Lancaster.

Fig. 97.



In Fig. 98, which represents the patent gully of Clark, of Carlisle, the trapping is effected in three places instead of two—first, by means of the shoot into the dirt box; second, by means of the cups in which the dirt box rests; and third, at the concave bottom of the gully itself. In this case the edging of the dirt box forms a grating to keep back any floating material likely to cause obstruction, while it lets the water pass away. This gully has been

adopted with success in several places, and Mr. Brentnall, the town surveyor of Tunbridge Wells, writes me that its efficiency is beyond doubt, especially if the silt boxes are frequently emptied. A gully made by Butt, of Gloucester, is of a somewhat similar description to the foregoing.

Fig. 98.

In Drawing XIV. I have given one or two other forms of gullies. Fig. 1 shows the double-trapped gully of Mr. Newton, of Manchester. It has been used extensively in the towns of Bolton, Blackburn, Rochdale, Preston, Huddersfield, Warrington, and Blackpool.

Fig. 2 shows Alexander's gully, which has been extensively used in Leeds, and Mr. Morant, the borough engineer of the town, tells me he has found it to answer well.

Fig. 3 shows an arrangement of gully designed by Mr. Lovegrove, C.E., and Fig. 4 a gully designed by Mr. Arthur Jacob, the borough engineer of Barrow-in-Furness.

Fig. 5 exhibits the gully to which I have referred when speaking of the flushing of sewers, and which serves the double purpose of a catchpit and a self-acting flush-tank.

A self-acting balance valve arrangement has been designed and manufactured by Messrs. Waller and Co. It is made of either galvanised or non-galvanised iron, and the cup is so weighted, or balanced, that the pressure of a greater quantity of water than is sufficient to help the cup to effect the desired trapping, or of solid matter to add weight to the water, will cause it to tip and discharge the contents into the sewer. I have already pointed out, and need not repeat, the objections which appear to me to exist to this character of trap.

Figs. 99 and 100 show an arrangement in which, in addition to the water trap, a metal flap or valve is so hung as to assist in cutting off the gas of the sewer.

The gully shown by Fig. 99 is one made by Messrs. J. G. Stidder and Co., of London. The trap is so arranged that it can be readily bolted to the side of the gully pit. It consists of a cast-iron facing-plate, to which is attached a hood dipping from above, and an inverted hood rising from below. A flap-valve is also provided, opening only towards the sewer. The water entering the gully passes beneath the edge of the upper hood and over the edge of the

Fig. 99.

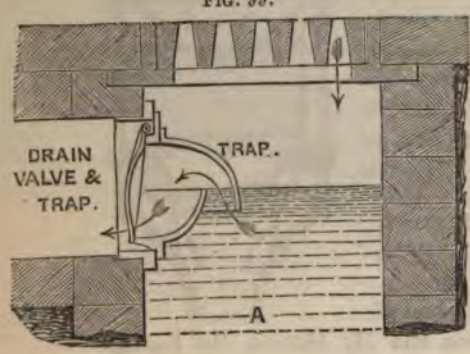
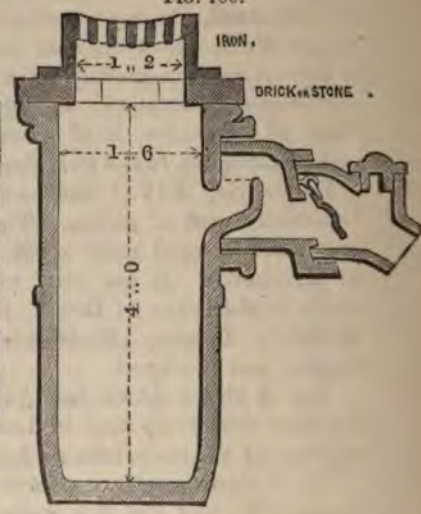


Fig. 100.



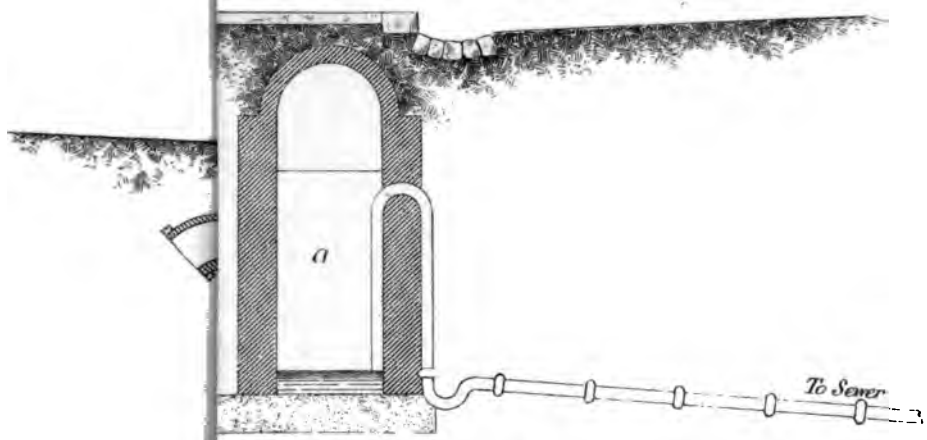
inverted hood, thus forming a trap when full of water. All water in excess of that required to fill the pit (A) passes through the valve to the sewer. The flap-valve in this description of gully is useful, not only as a stench trap to act when that formed by the water fails owing to evaporation, but as a means of preventing the passage of vermin.

The gully represented by Fig. 100 is one having a similar compound arrangement. It is made by Messrs. Doulton, and will be understood without description.

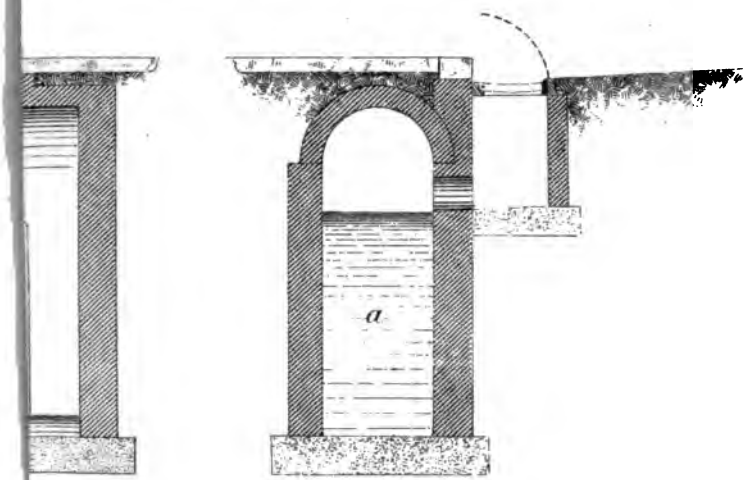
(4.) *Storm Overflows and Tidal or Outlet Valves.*—I have already referred in Section LXXII. to the necessity which exists of providing storm overflows for the escape of any excess of water which may find its way from the streets and roads into the sewers in times of heavy downfalls of rain. These storm overflows serve as safety valves to the sewerage system, and should be placed in such positions that a direct communication with the sea, river, or watercourse forming the natural outfall of the district may be readily gained. The precise shape they should take and the mode of connecting them with the sewers will be determined by local features. (See Drawings IX.[a] and XV., which exhibit overflows,—one into a river and the other into the sea.)

Mr. Baldwin Latham has suggested that the outlet drains conveying surface waters from streets and yards to a river should be so

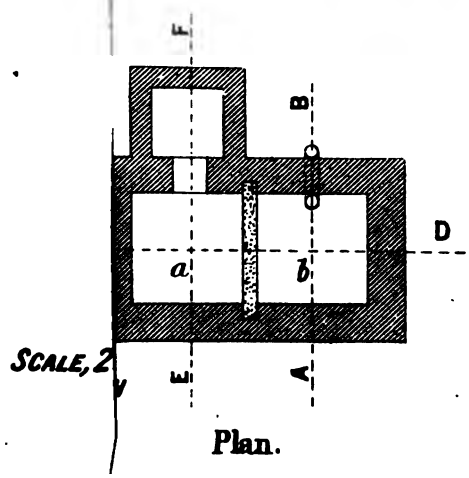
SELF-ACTING FLUSHING-CULLY. *FIG. 5.*



Section on line A.B.



C.D. Section on line E.F.



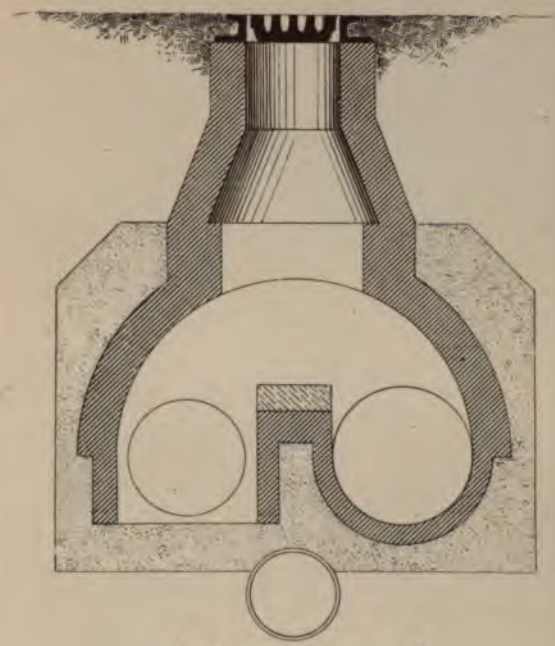
SCALE, 2

Plan.

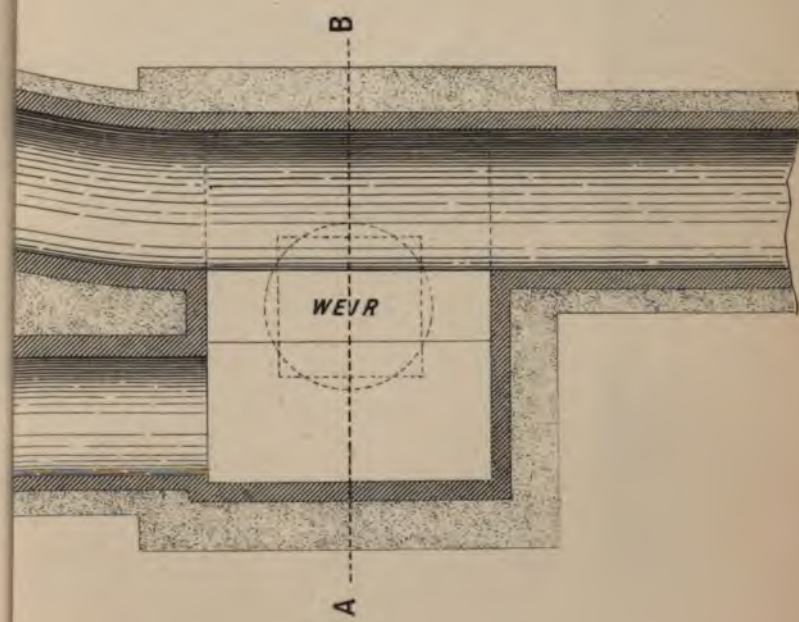
BAILEY DENTON, SON, & NORTH
22 Whitehall Place, LON

FIG. 2.

OVERFLOW WEIR FOR STORM WATER.

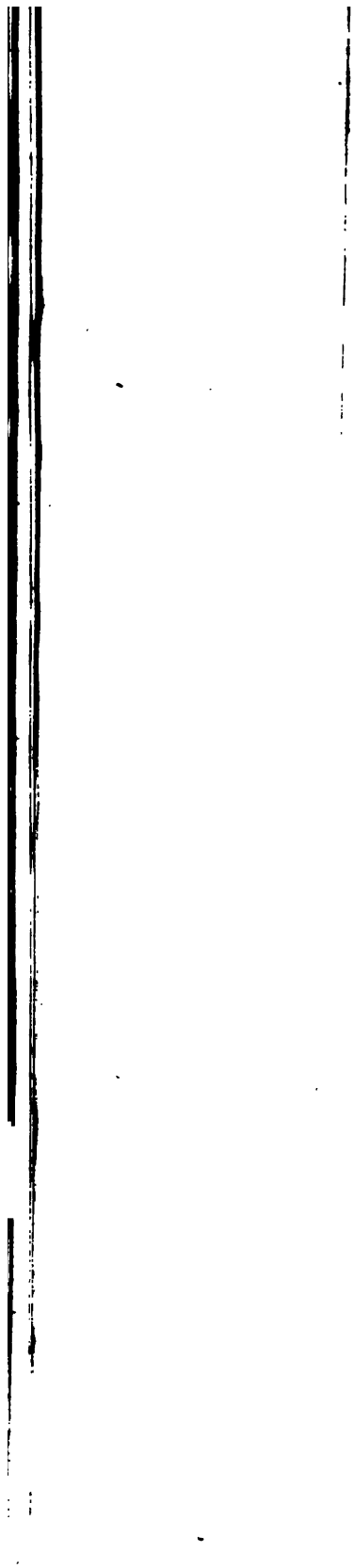


Section on line A.B.



Plan.

BAILEY DENTON, SON & NORTH
22 Whitehall Place, LONDON.



contrived and connected with any intercepting or outfall sewer which they may cross that they shall drop into it the whole of their contents up to a certain quantity, all excess beyond that quantity being carried forward by its own velocity to the river. This suggestion of Mr. Latham is illustrated by a drawing in his work on "Sanitary Engineering," and is described in the following terms:

"The sewer for conveying rainfall is assumed to be 2 feet in diameter, and has a rate of inclination of 1 in 550, and it is supposed to cross over the intercepting sewer on its course to a river. At the point the sewers cross an opening is made in both sewers,—in the bed of the rainfall sewer and in the crown of the intercepting sewer. In this case the opening is supposed to be 1 foot wide, and at the point of opening a sudden fall is given to the rainfall sewer, making a step of 2 feet in the sewer. When 3 inches in depth of rainfall flows through the rainfall sewer, the velocity of the current will be 1.6 foot per second, and in order to pass the opening 1 foot wide the step forming a weir should be 6.29 feet; but as it is only 2 feet, all the water flowing down the sewer would pass into the intercepting sewer. When 6 inches in depth of water is running through the 2 feet rainfall sewer the velocity of current will be 2·25 feet per second, and in order to pass the opening the stop should be 3·25 feet, so that this quantity will also pass into the intercepting sewer. When the rainfall sewer runs half full, the velocity will be 3 feet per second, and in order to pass the opening the step or fall should be 1·70 foot; but as in this case it is stated to be 2 feet, all the water brought down by the rainfall sewer will pass over the opening and will be discharged direct into the river, instead of passing into the intercepting sewer; and so by adjusting the width of the opening into the intercepting sewer or the amount of fall at the weir, any given amount of rainfall may be made to pass into the sewers, or be discharged into the streams of the district as may be required."

A somewhat similar arrangement has been adopted at Rochdale, by Mr. Hewson, the borough engineer.

Self-acting valves or flaps, of which Figs. 101 and 102 are examples, are also necessary provisions in most sewerage systems. Such contrivances are undoubtedly necessary wherever the sewers discharge into the sea, or into a tidal river below high water level, not only to prevent the inflow of the sea-water, but to keep out the wind and prevent the driving back of the sewer gases into the streets and houses in times of storms. Flaps are sometimes advantageously

Fig. 101.

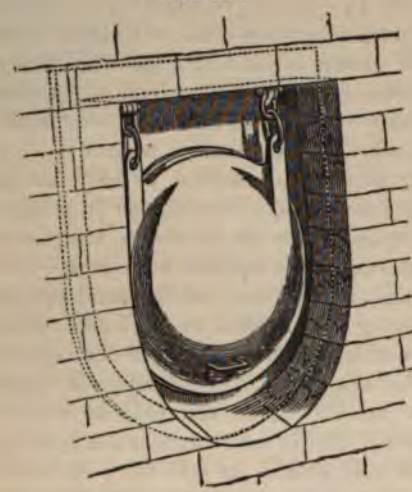


Fig. 102.

affixed to a sewer as it passes through a manhole, in order to prevent the onward passage of sewer gas generated below. Fig. 103 shows a light balance-flap of this character. It is made by Messrs. Flood and Co. By appending light flaps in manholes built in sewers with steep inclinations, the escape of effluvium may be so evenly distributed as to avoid objection. Flaps, similar to that shown by Fig. 104, are sometimes affixed to the junction of minor or private communicating pipe sewers with brick sewers, and are extremely useful, if well executed.

Fig. 103.

Fig. 104.

There are instances in which outfall sewers, discharging into tidal waters, exist without valve or flap of any kind, the sea-water being allowed to rise up them and mix with the sewage. This practice prevails at Liverpool, Ipswich, and many other towns, flooding the cellars on occasions of unusually high tides, and thus making it difficult to reconcile the practice with sound sanitary principles.

I need not observe that all tidal valves should be truly balanced and self-acting, so as to yield to the slightest pressure. They should, of course, be close-fitting to exclude the outer water. They should also, when facing the sea, be protected from the direct action of the waves, as the sudden motion of the valve backwards and forwards gives impulse to the sewer air, and causes it to force its way upwards into houses in defiance of traps and syphons.

Some very serviceable flaps for the ends of sewers and drains are made and kept in stock of different sizes by Messrs. Barford and Perkins, of Peterborough, and are illustrated by Figs. 105 and 106.

FIG. 105.

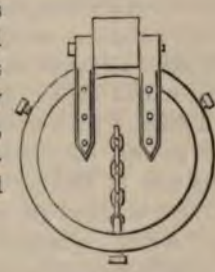


FIG. 106.

LXXXVI.—SEWER VENTILATION. Although there are few things connected with our subject so important, there is no doubt that up to the present moment the several means adopted for the ventilation of sewers have failed in the attainment of a satisfactory result. It is hardly necessary to say that wherever sewer gases escape into dwellings they have an injurious, if not a dangerous, effect, and that everything that can be done should be effected to prevent their entry. Uniform aëration of the common street sewers by frequent inlets of pure air and outlets of foul air seems the only means of ventilation which bears the test of experience.

Much has been said in favour of the use of charcoal to purify effluvium, and of all deodorising substances it seems to have the greatest power of absorbing and overpowering organic impurities. In support of it, the chemist declares that the destroying property of charcoal takes effect imperceptibly, and that "its power of burning organic

matter is continually renewed by the surrounding atmosphere, so that it is a constant carrier of atmospheric oxygen in a condensed state in its pores. The oxygen that acts on organic matter and burns it up is speedily replaced, and the process goes on continually. Hence it is that a comparatively small quantity of wood or peat charcoal is capable of destroying a large quantity of organic matter."—*Voelcker*. For these reasons charcoal has often been introduced, and placed in trays, within ventilating shafts. In one of the manholes shown on Drawing XI. the tray of charcoal may be seen. Mr. Rawlinson has had great faith in charcoal, and recommends it still. (See "Suggestions"). Mr. Latham too has patented a ventilator, and there can be no doubt that benefit may be derived from its use in certain cases, but such instances I believe to be few. The efficacy of charcoal depends so much upon its being kept free from dust and in a dry condition, that its purifying functions, when used in connection with sewers, soon cease to have any effect. Where, therefore, aëration can be gained by manhole and lamphole openings at regular and frequent intervals throughout the sewerage system, with occasional shafts for ventilation only, aided by private ventilating outlets above dwellings, recourse to charcoal is undesirable. It is in fact so often an evil rather than a benefit, that as a rule charcoal should be discarded from sewerage systems. In this view there is now a very general concurrence amongst engineers. Mr. Jones, the town engineer of Ealing, says that his "experience of charcoal trays and cages is not at all favourable to their use, unless the charcoal is *very frequently* changed. When closely packed, the layers do not act as ventilators; when loose, the charcoal has but little effect upon the gas, and when charged with moisture is, so far as gas is concerned, valueless." Mr. Lemon, the borough engineer of Southampton, says: "I have come to the conclusion that charcoal trays in the ventilating shafts are of no use, and have decided to abandon them." In another letter he adds that the use of charcoal stops the outflow of impure air, and "does more harm than good." Mr. Pritchard, the engineer of Warwick, says that he has removed the charcoal from existing manholes and substituted open ventilation, adding, that he looks upon this system as the only perfect one of ventilating sewers. Mr. Coghlan, of Sheffield, says: "I do not find it necessary to use charcoal trays in manholes, and certainly have never used any. Unless they have careful attention, and the charcoal is constantly replaced, they become no better than a wet blanket." Mr. Buckham, the engineer of Ipswich, says he does not approve of fixing charcoal in the ventilating shafts of any system of sewerage.

Mr. Banks, the borough engineer of Kendal, says: "I used to use charcoal in all my ventilators, but it is practically more injurious than having none in at all. I found that, unless we changed it frequently, in the course of two or three days it got so damp and clogged from our constantly damp atmosphere, that the passage of sewage gas through it was completely stopped, and it acted as a bung to the only outlets of air from and the inlets into the sewers."

As already stated, the object to aim at is the complete and uniform aëration of the whole sewerage system, and to effect this nothing more is requisite than the existence of a sufficient number of open ventilators in the shape of manholes, lampholes, and shafts up to the level of the streets—assisted by light flaps in some manholes, as already described—and the effective ventilation of private communicating sewers by shafts or pipes reaching above the roofs of the houses. With this provision the accumulation and escape of sewer gas in an excessive and objectionable quantity at any one place is practically impossible; but the proper supervision of private dwellings, with respect to the ventilation of their soil pipes, is an essential part of the arrangement.

The following valuable remarks, extracted from Mr. Waring's recent work, entitled "Sanitary Drainage of Houses and Towns,"* express so clearly what I would myself further say on the subject, that I prefer to quote them rather than to add to my own.

"The principle of the ventilation of a sewer is practically the same as that adopted by builders for the prevention of dry rot. The fungi which cause this rot in timber cannot produce their germs in a current of air, and if a sufficient number of ventilating openings are made, communicating with each other, the action of the wind from one side or the other will cause a sufficient current. So in a sewer a continuous movement of the air in one direction or the other carries away and dilutes sewer gases, and if they contain germs of organic disease capable of infecting the human blood, these are believed to be destroyed by oxidation or otherwise.

"A safe sewer always has a current of air passing through it, and if it contains sewage matters at all, these also must be in constant motion. On this incessant movement of the air and the liquid must we rely for our only security. A solution of sugar in water, remaining stagnant, and protected from a free circulation of air, will enter into a vinous fermentation. If well ventilated and agitated, no such fermentation takes place. It is asserted that the

* Published by Hurd and Houghton at New York.

excrement of a typhoid patient, continually agitated in contact with fresh air and a fair admixture of water, passes through a series of complete chemical changes, with no injurious product; but if allowed to remain stagnant, if not freely exposed to the air, or if it gain access to human circulation before a certain oxidation, it will, like a ferment, reproduce itself, and give rise to the conditions under which it was itself produced. Motion and aëration are therefore needed to prevent infection, which is sure to be generated when typhoid evacuations are confined and stagnant. Unventilated and badly constructed sewers are sure agents for the propagation of the disease when once it has taken root.

"The resulting gases of sewer decomposition are the vehicle or medium for the conveyance of infection, and from their lightness they give rise to a rapid diffusion, owing to the eagerness with which they seek means of escape at the higher parts of the sewer system, that is, in house drains, soil pipes, &c. It may not be possible entirely to prevent the development of the poison in even the best arranged sewer, but it is possible, by a free admission of air, to supply the oxygen which will take away its sting and render it harmless. Sewers which have large and frequent openings at the street surface, and through which the liquid contents have a constant flow, may give forth offensive smells, but, if they have proper attention, sanitary evils do not often result.

"Sewer gas, when largely diluted on its escape (at frequent intervals) into the air of the street, is probably nearly or quite innoxious, but when it forces its way into the limited atmosphere of a closed living-room, the poison, or the germs of disease accompanying it, may easily work their fatal effects.

"Sulphuretted hydrogen is found in all sewers in which the sewage itself or the mucous matters adhering to the pipe assume a certain degree of putridity in the absence of a sufficient supply of fresh air. This gas is extremely poisonous; so much so that one part of the gas to two hundred and fifty parts of atmospheric air will kill a horse. At one half this intensity it will kill a dog. A rabbit was killed by having its body immersed in a bag of it, although its head was not inclosed, and it could breathe pure air freely.

"One of the most frequent sources of pressure upon the air within a sewer is the increase of temperature arising from the hot water escaping from kitchens and baths. The repeated expansions and contractions caused by the admission of hot and cold water produce a constant effect on all water traps connected with unventilated sewers. With ventilation, the breathing in and out, as the air of the

sewer contracts or expands, does not affect the water traps, because an easier passage is found through the ventilators.

"The constantly changing volume of water in many sewers, as has been before stated, exerts a powerful influence on the confined air. As the water rises it reduces the air space, and if it reduces this to one-half, it brings to bear upon the air a pressure equal to a column of water thirty-four feet in height, and this pressure is relieved by a forcing out of air through the most available channel—the channel where there is the least resistance; if there is no other vent, a sufficient number of water traps must be forced to allow the pressure to become reduced. It being reduced, and the water falling again to a lower level, a vacuum is created which must be supplied by air forcing the traps in a reverse direction, and in either case the forced trap may remain open for the free passage of foul air until another use fills it with water. In the ebb and flow, too, a part of the perimeter of the sewer is made alternately wet and dry, with an accompanying production of vapour and gas.

"As the chief domestic use of sewers is between morning and noon, and as at this time the most hot water passes into them, the pressure on the air in the sewer is during this period increased both by an elevation of the temperature and by a reduction of the air space. Then, from about noon until the next morning the quantity of the flow decreases, the air space increases, the temperature falls, and more air must be admitted to supply the partial vacuum created. Such fluctuations are constantly occurring, accompanied with a drawing in and forcing out of air, for which ample passage *must* be made, independently of the water traps of houses, or sewer gas will surely enter them. Where proper air vents are provided, this ebb and flow of the sewer may be increased, with great advantage in the matter of ventilation, by artificial flushing arrangements, which will allow the water to be dammed back and released at frequent intervals."

LXXXVII. — Scavenging of Towns and Villages. I do not propose here to explain in any great detail the different modes of excrement-collection, disposal and removal, forming the work of scavengers, which prevail in different towns of this country. I may, however, state shortly that they consist of (1) the midden and privy systems, (2) the pail system, and (3) the dry closet system.

The midden and privy systems of disposal consist of closets pro-

vided simply with receptacles for the excretal refuse, some being fixed, and some moveable.

The pail system consists of closets provided with portable receptacles specially prepared for use.

And the dry closet system consists of the use of material prepared to deodorise and absorb the liquid and facilitate removal.

1. The "*middens with fixed receptacles*" comprise the old privy with its cesspit, such as exist in nearly every country village, as well as the closets in connection with ash-pits, which more generally prevail in the northern counties. Middens or privies with fixed receptacles vary in character as well as in size and construction. They are more or less offensive according to the extent to which their contents are deodorised or soaked up by ashes or other solid refuse.

It is indeed surprising that so many receptacles of putrefying human excrements as are known still to exist, should be allowed to remain in the midst of populations in spite of our progress in sanitary science in recent years. In the towns of the northern counties and in the villages of the south, water or earth are only exceptionally used as vehicles of removal. Nevertheless these privies are the means of spreading, to an enormous extent, what Mr. Simon, C.B., the medical officer of the Privy Council, has termed "*filth diseases*,"—cholera, enteric or typhoid fever, and diarrhœal complaints. The character of the privy is thus graphically described by Mr. Simon in his Supplementary Report to the Local Government Board, 1874. He says: "Either it has had no other catchment apparatus than the bare earth beneath the privy seat," . . . . "or else it has had as supplement to the privy, a large enclosed midden-stead or cesspool, partly or entirely of brickwork or masonry, intended to retain large accumulations of the solid filth, with or without the ashes and other dry refuse of the house, and in general dividing its fluid between an escape channel especially provided and such soakage and leakage in other directions as the construction has undesignedly or designedly almost always permitted. Privies such as these have not been meant to have their filth removed except where its mere largeness of bulk (exceeding or threatening to exceed the limits of the privy pit, or cesspool, or midden), might mechanically make removal necessary." . . . . "What nuisance this system at present constitutes in innumerable populous places, including some of our largest towns, can indeed hardly be conceived by persons who do not know it in operation, and the infective pollutions of air and water supply which it occasions to an immense extent in towns and villages throughout

the country are chief means of spreading in such places some of the most fatal of filth diseases."

Every sanitary authority—rural as well as urban—is bound by law to see that these privies are so constructed as not to be a nuisance, and yet in the Report of the Medical Officer of the Local Government Board,*—under the head of "Illustrations from Inspectors' Reports of the four years 1870-3 of the circumstances in which enteric fever is commonly found prevalent,"—we read these words, when speaking of towns which shall be nameless here:

"Enteric fever. Polluted wells. Air and soil befouled with excrement from cesspits. General neglect of sanitary measures."

"Enteric fever. No public drainage. Open cesspools. Sewage soaking into wells."

"Constant prevalence of enteric fever. Soil round wells sodden with soakage from privies."

Much has been done of late years by the leading medical officers of health and sanitary inspectors to point out the existence of this state of things, yet at this very moment leaky sewers, no better than leaky cesspits, are being constructed in both towns and villages, while water obtained from wells sunk in the same soil, is allowed to be consumed by the inhabitants.

In towns, the existence of cesspit-privies should be prohibited altogether.

In villages where the disposal of excretal refuse may be very difficult, everything that the sanitary authorities and their officers can do should be done to compel the removal of these cesspit-privies to positions away from both the well and the house,—to enforce the construction of the cesspit in a water-tight condition,—and to ensure the frequent removal of its contents. As an essential step to success, means should be taken to secure the removal of the contents by a public scavenger in every instance where they are not removed by the householder sufficiently often to avoid nuisance.

"Middens with moveable receptacles" such as are now coming much into use in Manchester and other northern towns, form an improvement upon the old privy or midden cesspit. They allow of the ready removal of the excreta, and as the receptacles are of a comparatively small size, they luckily necessitate frequent emptying. When specifying this advantage, however, it should be mentioned that it is all that can be said in favour of the system.

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* Supplementary Report, 1874.

2. The "*pail system*" differs from the system just described in having some material placed within the receptacle either to absorb the liquid and deodorise the solid contents, or to deodorise them only. The "pails" are removed at regular and frequent intervals, and are therefore preferable to privies or middens with fixed cesspits.

One of the most successful instances of the pail system is that invented by Mr. Alderman Taylor, of Rochdale, and carried out in that town. There the contents of the ash-pits, as well as the excreta of the closets, are collected by the town scavengers. The manner of operating is thus described by Mr. Taylor in a statement prepared for a recent meeting on the "Health and Sewage of Towns," held at the Society of Arts (May, 1876):

"The town is divided into six divisions, named A, B, C, D, E, and F. Each division has its corresponding books, the pages being ruled into thirteen weeks. In the books every excreta pail and ash-tub is entered in progressive number, and the street recorded in which it is placed. Vans and ash-carts are appropriated for the collection, and the guard is furnished every morning with the names of the streets and number of closets in that street, written on a ruled blank list, which he has to collect. When the van or cart returns, it is weighed, and the list given to the weigh clerk, in the ruled squares of which the guard has entered the pail or ash-tub number which he has brought in. The van is then emptied, the washer of the pails taking an account of the total number brought in by each van. An inspector daily enters from these lists into the division book the numbers of the pails brought in, and is thus able to say at the close of the week if every closet has been attended to, and if not, a van is specially sent for the pail omitted. It is found that, with this oversight, the number omitted collecting in regular order has not exceeded thirteen per week.

"The pails are thoroughly washed, and into each is put a portion of chloride of alumina, and sulphate of lime. The excreta is emptied from the pails into a trench formed of fine ash, which has been sifted from the refuse and cinders collected by the ash-cart. A quantity of sulphuric acid, 30 lbs. to one ton of excreta, is poured into the trench, and the whole mixed. In three days the trench is turned over with a spade, and again in twenty-one days, by which time the whole will have become in a tolerably dry state, containing about 35 per cent. of water. Before the sale of the manure it is again turned over and screened. The quantity of excreta to ash used at present is 7 cwt. of ash to 1 ton of excreta.

"The ash-carts pour their contents into the hopper of a sifting

machine, which separates the fine ash, fine cinder, rough cinder, vegetable matter, glass, pots, and rags. The disposal of this refuse is by using the fine ash for manure, the fine and rough cinder for fuel for the steam boilers, and for sale; the vegetable matter is burnt, and the ash from it ground and added to the manure, for the sake of the potash; the clinkers and pots are ground up for mortar and cement, and the rags, glass, and iron sold."

The details of the quantity of excreta and refuse collected, together with the dry manure made from them, and its cost, will be found in the Appendix; and in the Appendix will be found also some other valuable details of similar plans adopted at Warrington, Birmingham, Nottingham, and Blackburn. I would point out that at Rochdale and elsewhere the accumulations of the mixture are very considerable.

The system known as the "Goux Absorbent Pail System," has recently found much favour, and has been adopted in several places. It has been tried for some years at Halifax, where the liquid sewage of the sewers is still permitted to flow into the Calder in an unmitigated condition, and upwards of 3000 closets on the Goux principle are now in use there. It has been adopted also at the Camp at Aldershot, at Sheerness, and at Woolwich. The system is thus described by the manager of the company (Society of Arts, May, 1876):

"A tapering tub or container is provided, say 16½ inches high, and 20 inches at its greatest diameter. Upon the bottom of the tub is placed 3 or 4 inches of refuse, such as new stable litter, loft sweepings, stack bottoms, ferns, shavings, sawdust, shoddy, flax dressings, spent tan, or hops, or the various waste materials to be found in town or country; this is mixed with a little soot, charcoal, gypsum, or other deodoriser, for the purpose of packing or lining the tub. A mould of the same shape as the tub, but 6 inches less than the internal diameter, is placed upon the 4 inches of absorbent material referred to, and the space between the mould and the tub is packed with the same kind of refuse. One boy can pack eighty tubs in an hour, and this is all the manipulation required, except placing and removing the tub at stated times. The absorbent material having been only moderately pressed down, the mould is withdrawn, and there remains a cavity into which the dejections fall, the liquid parts of which are taken up by the absorbents, and retained by them, so as to check fermentation."

Dr. Alfred Haviland, the medical officer of health for Northamptonshire, speaks very highly of this system of excreta collection,

and after an examination into its working at Halifax recommends its adoption.

3. The *dry-closet system*, already spoken of when treating of the dwelling (Section LXII.), will be found more applicable to villages than the pail system for excretal removal, because there can be no difficulty in obtaining the material required for use. Most kinds of earth if used in sufficient quantity act as a deodoriser of excretal matter. "Clayey and loamy soils and surface moulds are best; chalk is of little use, gravel and sand are worthless." * The material must be dry and loose—approaching the character of sand, and a sufficient supply in a dry state should be stored under cover and kept ready for the replenishment of the closet when necessary. Dry earth may be used in closets with fixed pits as well as in those with moveable receptacles. The use of the latter is the better arrangement. Charcoal in lieu of earth answers the purpose equally well, if not better, and a much less quantity—about one-fourth—will suffice; but charcoal is more difficult to obtain and more expensive than dry earth, and will probably only grow in favour with the wealthier classes.

Anticipating the adoption of the dry earth system in villages, as well as in isolated establishments, it may be well before leaving the subject of the dry removal of excrements, to give here the substance of a report made to a considerable landowner by his agent, after a personal examination of the system adopted on Sir Anthony de Rothschild's estate at Halton. "The apparatus used," he says, "is that of Moule's Dry Earth Closet Company. The 'pull out' apparatus, after some years' experience, has been found the one most approved by those using them on account of its simplicity and cheapness, and its less liability to get out of order and to waste the dry earth. Vaults are now substituted at Halton for pails and tanks. They answer satisfactorily excepting in one or two cases, where they are not properly water-tight. Sir Anthony Rothschild employs a man (a scavenger) to look after the whole of the closets on his estate—whether they be attached to the cottages or farm-houses—whose duty it is to provide the dry earth, supply the hoppers of the closets with it as often as may be necessary, and also to remove the soil from the vaults to be dried for use a second time. There are on Sir Anthony's estate alone about 170 to 180 dry-earth closets, for the proper supply of which about 200 tons of earth are required annually. This is dug and screened in dry weather, and carted to

* Mr. Netten Radcliffe's Supplemental Report to Local Government Board, issued 1874.

a large open shed. There is in this shed a kind of kiln 9 feet by 9 feet by about 2 feet deep, the bottom of which is thick sheet iron with bricks for the sides. Underneath there is a fire, and several flues run under the sheet-iron bottom. On this kiln the earth is dried—about two cart-loads at a time—a good stock of the fire-dried earth being at all times on hand. The man, two or three times a week, takes a cart-load of dried earth round and fills all the hoppers, and, if necessary, levels the soil in the vaults below. The vaults are emptied at intervals, varying from six weeks to three months, according to the size of the families using them. After the first time of using, the soil is taken to the shed and stored till the whole of the dry earth has been once used, when it is all dried in the kiln ready for use a second time. After the second time of using it is taken and stored, and is used as a manure, latterly for planting trees and shrubs, but formerly for agricultural purposes. The closets are not expensively built, but they are well attended to. They are patterns of decency and cleanliness. Not the least smell of any kind was perceptible except where the vaults were not water-tight, and they, of course, approximated very nearly to the condition of the common privy. Dry closets are in use at all the schools on the whole of the Rothschild property."

The "Cinder-sifting Ash-closet" system, to which I have also already referred when treating of the dry closet system of the dwelling (Section LXII.), has been tried as a town means of scavenging by the corporation of Salford in the Pendleton portion of their district. Mr. Walter Pearse gives the following account of his operations:*

"More than 1,000 of the closets are in use in the district; but the following statement of the result achieved by the system is based on the working of 1,000 closets. Each pail receptacle contains 1½ cwt., and, with an ordinary family, requires to be changed every week. Thus, 1,000 closets produce 75 tons of manure per week, or say 3,900 tons of crude manure per annum.

"The full pails are conveyed in covered vans to manure works, especially constructed by the corporation at Windsor Bridge, and alongside the canal. The works embrace an open receiving yard, a shed containing a mixing mill and a mortar mill, driven by a steam engine, a space for storing the manure and mortar made, a weighing machine, and a small office. The receiving yard is on a higher level than the floor on which the produce of the works is stored.

"The excrementitious mass from the pails, after passing through

* Conference at Society of Arts, May, 1876.

the iron mixing trough, together with a small quantity—one quarter hundred weight per ton—of sulphate of lime, comes out a consolidated manure of uniform consistency, which obtains a ready sale at 12s. 6d. per ton.

"Garbage and other rough material found on the premises, including cinders not re-burnt by the occupants of the houses, are also conveyed to the manure works by the same van which collects the pails. The garbage is separated and sold direct at the rate of 3s. a ton, while the remaining rough material is ground, and by the addition of 3 cwt. of lime to the ton, is converted into mortar, and sold at 5s. a ton.

"The labour required per 1,000 closets is only that of 2½ horses and 12 men, including the collection and the process of the works. The financial result is as follows:

	Tons.		£	s.	d.
Manure from pails	3900				
Sulphate of lime added	50				
	3950	Per Ton. at 12s. 6d.	2468	15	0
Garbage...	456	,, 4s.	91	4	0
Mortar made	130	,, 5s.	32	10	0
			2592	9	0

"Less expenditure as follows:

	£	s.	d.			
2½ horses and 12 men per annum ...	821	12	0			
Sulphate of lime, 50 tons at 8½d. per cwt.	35	8	4			
Lime for mortar, 20 tons at 8½d. per cwt....	14	3	4			
Interest and depreciation on amount expended on works, viz., 1000*l.* at 10 per cent.	100	0	0			
Fuel and engineer's wages	146	2	4			
				1117	6	0
Total nett profit to Corporation				1475	3	0"

A very careful inquiry into the working of several of the systems of excrement removal adopted throughout the country, was made by Dr. Buchanan and Mr. Netten Radcliffe in 1869, and again by the latter in 1874. Their reports upon the subject to the medical officer of the Privy Council and Local Government Board furnish much information of a very practical character, and are well worthy

the study of the sanitary engineer. The result of their inquiries may be quoted in the same order as that I have adopted, as follows:

(1.) "The midden system may be modified so as greatly to reduce nuisance and danger from it. Satisfactory safety in the use of even the best forms of midden closets cannot be averred with certainty, partly because there is no prospect of such closets being emptied daily, and partly because the materials of the midden-stead would probably be retentive of some excremental matters.

(2.) "The pail system presents several advantages over the old midden system for poor town districts. The system involves construction or constructive alterations similar to those required for the toleration of a midden system, and offers peculiar advantages over the latter in regard to facility for frequent removal of excrement, and to completeness of such removal in regard to safety from nuisance, and probably in regard to profit in disposing of excrement as manure. The pails, of defined construction, should be changed daily for fresh ones in all crowded neighbourhoods, and when used by several families in common, or by numerous individuals, and under no circumstances should they remain unchanged more than one week. It is essential to the proper working of a pail system, that it should be carried out in towns and villages by the sanitary authority.

"Those who use the closet may both under the pail and the midden system be expected, with due superintendence, to do the cleansing of it so far as merely affects ordinary comfort and decency; but such action as concerns the effectiveness of the closet as a means of excrement removal must be taken by the sanitary authority itself.

(3.) "The earth system, intelligently managed, furnishes a means of disposing of excrement without nuisance, and apparently without detriment to health. In communities, the earth closet requires to be managed by the authority of the place, and in limited communities it will probably pay at least the expenses of its management. In the poorer class of houses, where supervision of any closet arrangements is indispensable, the adoption of the earth system offers especial advantages.

"With both the pail closet and the earth closet everything depends upon the care and regularity with which the deodorising or absorbing material is supplied, and the contents of the receptacles are removed. In all towns and villages, where a dry system of

excrement removal is adopted, it is essentially necessary that this duty should be performed by one man under the orders of the sanitary authority, and not left to individual performance."

In addition to the frequent removal of the contents of the privy and closet, the periodical removal of the material thrown upon the ash-pit or dust-bin should have the most careful attention of the sanitary authority of a town. I have already referred to this description of refuse (see Section LXII.), but I should nevertheless like again to lay stress here upon the necessity which exists for the exercise of the utmost vigilance on the part of sanitary officers in seeing that the material so collected is properly dealt with. It comprises not merely the dust and ashes from the dwelling fires, but a considerable amount of organic matter—in some instances reaching to the whole of the animal and vegetable refuse of a dwelling—besides. The putrefaction of this mass of filth, aggravated in its effects by exposure to the sun and rain, takes place in many instances in towns and villages so near the dwelling that it cannot fail to be a source of danger to health. The scavenging arrangements of a town or village should therefore be so made as to secure the removal of these collections before they have had time to become offensive, and any failure on the part of the occupier should be made good by the sanitary authority. The duties of the scavenger, in fact, are of the first importance in all places where dwellings are congregated together.

Mr. Simon says, "There are groups of houses, there are whole villages, there are considerable sections of towns, there are even entire and not small towns, where general slovenliness in everything which relates to the removal of refuse matter, slovenliness which in very many cases amounts to utter bestiality, or neglect, is the local habit; where, within or just outside each house, or in spaces common to many houses, lies for an indefinite time, undergoing fœtid decomposition, more or less of the putrefiable refuse which house-life, and some sorts of trade-life, produce; excrement of man and brute, and garbage of all sorts, and ponded slop waters; sometimes lying bare on the common surface; sometimes unintentionally stored out of sight and recollection in drains or sewers which cannot carry them away; sometimes held in receptacles specially provided to favour accumulation, as privy-pits and other cesspools for excrement and slop water, and so-called dust-bins receiving kitchen refuse and other filth. And with this state of things, be it on large or on small scale, two chief sources of danger to life arise; one, that volatile effluvia from the refuse pollute the

surrounding air and everything which it contains; the other, that the liquid parts of the refuse pass by soakage or leakage into the surrounding soil, to mingle there, of course, with whatever water the soil yields, and in certain cases thus to occasion the deadliest pollution of wells and springs."

It is the prevention or removal of all these nuisances which, under proper regulations, should be the duty of the scavenger.

In every case the contents of the ash-pit or dust-bin should be protected against rain and sun.

In concluding this section, I will only add that in making arrangements for the adoption of any system of dry collection of excreta and solid refuse, special attention should be given to the site for the storage and treatment of the collected materials. A thickly populated neighbourhood should certainly be avoided, as should also such a site as that selected at Manchester, where on one side of the road may be seen the town dust-yard, and on the other the abbatoir where the meat supply of the city is killed and dressed!

LXXXVIII.—On the Water Supply of Towns and Villages, with Remarks on Constant Service. The remarks which have been already made under Divisions II. and III., with respect to the sources whence the supply of water to the dwelling may be obtained, and the means by which that supply may be raised and delivered, will apply with equal force to the village and the hamlet, and may be even useful to the student in sanitary engineering when dealing with the supply of larger places.

I do not here propose to treat of the works necessary for the supply of water to large cities and towns, for they would necessarily be of too comprehensive a character to be considered when dealing generally with sanitary engineering. I shall content myself with making a few observations on the *distribution of water* in a manner most acceptable to the consumer yet consistent with due regard to the interests of the company or authority supplying the water.

It is now generally conceded that from a sanitary point of view the delivery of water by constant service at high pressure is an object which should in all cases be aimed at. By the term "constant service," I do not mean a supply which is so curtailed by pea or pin ferrule as to be a mere dribble; but a sufficient delivery of water for all purposes and at all times to meet every reasonable requirement immediately it arises, the water being drawn direct from the main without the interposition of any service cistern or storage

tank, which, as I have already said, is more frequently than anything else the cause of pollution in domestic water supply.

Let me describe the "pea" or "pin" ferrule which has only come into existence within recent years as a means of protecting the water companies against waste. I do not know that I can do so better than in the words used by Mr. Taylor, the engineer of the Lambeth Water Works, and referred to in his evidence before the Commissioners appointed in 1872 by the Board of Trade to inquire into the regulations for a constant supply of water to the metropolis. He says: "This ferrule has an internal disc in which is a small hole with its area proportionate in a sort of inverse ratio to the pressure of water where it is applied, being intended to restrain the flow where the pressure is great. This sort of ferrule is generally harmless enough, if not beneficial to all parties, providing that the orifice is not too contracted; but to apply it in the manner above alluded to, so as to dribble out the water at the rate of 20 gallons per head in 24 hours, or less than one gallon per head per hour, does indeed seem a ridiculous apology for constant service, and a device which can neither benefit the public nor the companies."

Mr. Bramwell, C.E., when speaking of this contrivance,* said:—The pea ferrule "was a well-known term, and was a proper term when, as the name implied, the hole would pass through it a pea of ordinary size. No doubt such a ferrule in many cases—as in Sheffield, for instance, where in some zones there was a pressure of 300 feet of water—was very desirable, as without some such reducer of velocity when a child went to draw water in a jug the jug must be knocked out of its hand by the water dashing against the bottom; but the contrivance used by the company in question"—a London water company—"was not a pea ferrule, it was a pin ferrule, with a hole $\frac{1}{24}$ inch in diameter, the object being to give one pint of water a minute, or from 180 to 200 gallons in 24 hours." To realise the effect of this obstruction I may mention that a person desiring an ordinary bath must wait about two hours to procure sufficient water from the main for the purpose if it is drawn through a pin ferrule.

So general is the concurrence expressed by all persons unconnected with water companies in the advantages of avoiding house cisterns, that it is scarcely necessary to refer to the opinions of any one, however high he may be as a sanitary authority, in support of

* Proceedings of Inst. C.E., vol. xlii., part iv.

the same view. I will, however, give you a few sentences from evidence given by Mr. Simon. He said: "I consider the system of intermittent water supply to be radically bad, not only because it is a system of stint in what ought to be lavishly bestowed, but also because of the necessity which it creates that large and extensive receptacles should be provided, and because of the liability to contamination incurred by water which has to be retained often during a considerable period." . . . . . "The long retention of water in leaden cisterns impairs its fitness for drinking." . . . . "On the extreme inconvenience which attends the storage of water in the poorer habitations of the city, I have already reported to you, and will now only add that increased experience has given much confirmation to my view. These receptacles are generally such as contribute to the contamination of water, and are constantly so arranged as to invite an admixture of the most varied impurities." . . . . "The butt or cistern of the house, that on which the inmates depend for their supply of fresh and pure drinking water, is placed in immediate contiguity to the privy, so as to reduce the requisite length of connecting-pipe to the fewest possible number of inches; the application of water is not made discretionary on the users of the privy, nor are any of the cheap and common self-acting contrivances introduced; but the waste-pipe of the butt or cistern is conducted into the discharge-pipe of the privy, so that periodically with a frequency varying according to the arrangements of the water company, the arrears of excrement are removed so far as the overflow of the water receptacle may have power to dislodge and propel them." . . . . "Water, as you probably know, is a very active absorbent of many gaseous materials."

The Rivers Pollution Commissioners in their report dated 30th June, 1874, state: "All storage of drinking water in houses is attended with the risk of pollution. Good water is spoiled, and bad water rendered worse by the intermittent system of supply. All drinking water ought to be drawn direct from the main. Under proper supervision the waste of water is less on the constant than it is on the intermittent system of supply. These and other advantages have led to the adoption of the constant system in a great majority of British towns."

The argument used against a constant supply is, that it encourages, and in practice results in, extravagance on the part of the consumer, and that no provision which can be made by any sanitary authority or private water company, however great, can be main-

tained with economy where such latitude exists. The answer to this is, that neither extravagance nor waste need be experienced under proper management and the use of proper appliances. This is, to a great extent, proved by the fact that in certain towns where a constant supply is now in use with the advantage of proper precautions to prevent waste, the quantity consumed is not more than from 14 to 16 gallons per person per diem. A comparison of the following figures (taken from the Sixth Report of the Rivers Pollution Commissioners) relating to twelve towns supplied with water on the constant system, and an equal number of towns supplied on the intermittent system, conclusively shows that there need be no more waste in the constant than in the intermittent system.

TOWNS	Supplied on Constant System.				TOWNS.	Supplied on Intermittent System.			
	No. of Houses.	Factories.	Gallons supplied Daily.			No. of Houses.	Factories.	Gallons supplied Daily.	
			Total.	Per House.				Total.	Per House.
Birmingham	68,532	...	7,500,000	110	Bath	4650	...	402,000	86
Cambridge	5,680	150	385,000	68	Beaumaris	380	...	65,000	170
Cheltenham	5,000	...	350,000	70	Birkenhead	7600	20	1,860,000	244
Chester	6,000	...	1,250,000	200	Exeter	7000	...	862,000	123
Eastbourne	1,600	...	500,000	300	Gravesend ...	3000	...	225,000	75
Lincoln	5,079	...	260,000	52	Oxford	5500	...	1,200,000	218
Macclesfield	8,637	56	1,000,000	120	Shrewsbury	4800?	...	500,000	105
Newcastle-on-Tyne.	43,153	...	4,700,000	110	Skipton	1160	...	150,000	125
Rochdale...	13,000	...	750,000	60	Tunbridge Wells...	2036	...	200,000	100
Salford	15,000	...	1,100,000	72	Torquay...	2000	...	600,000	300
Southport	3,600	...	600,000	166	Winchester	2250	...	250,000	110
Wigan	8,000	...	700,000	66	Worthing	1600?	...	120,000	75

The figures here given, indeed, plainly show that a wasteful consumption of water is not inherent to either one system or the other, but is entirely due to the want of *effective control and proper appliances*. I would lay great stress upon these desiderata. In support of this view, the Rivers Pollution Commissioners say with respect to Lincoln, a city in which there are upwards of 5,000 houses, and which occupying the summit and sides of a hill presents great variations of level, and therefore great irregularity of pressure, that experience shows that the inhabitants are sufficiently supplied with 260,000 gallons of water daily on the constant system, "the inspector having power not only to examine all the fittings throughout his district, but to repair them after due notice at the expense of the tenant; while at Oxford, half the population of the city

corresponding to about 5,500 houses, use 1,200,000 gallons daily, although the whole supply is shut off during the night time." This illustration is a very striking one. If we compare the consumption of water at Oxford with that at the sister university town of Cambridge, we find that a similar number of houses are supplied with a sufficiency though the amount consumed does not exceed 385,000 gallons, or about one-third of the quantity used at Oxford. These remarks may be supplemented by figures given in the tabular section XIX., showing the water supply of different towns.

The waste that actually does take place under the constant system of supply, and which the sanitary engineer should do his best to prevent, is due to several causes. They may be divided as follows:

(1.) That which occurs by the escape of water from the supply mains and junction pipes before the water reaches the dwellings of consumers.

(2.) That which arises from the escape of water after it has reached the dwellings by careless consumption or wilful abuse.

(3.) That which is due to the use of improper and imperfectly fitting taps, ball valves, and other appliances.

The prevention of the waste due to the *first* cause wholly depends upon and must rest with the authority or company supplying the water. It is seldom that defects from this cause exist, though it is sometimes found that when an intermittent supply is changed to a constant service, the extra pressure involves the relaying of some portions of the service pipes.

The *second* cause of waste is only to be prevented by proper supervision on the part of the supplier, and the introduction of waste preventers, such as the waste-not and self-closing appliances, which I have already explained when treating of the dwelling (see Section LX.). Under the Water Works Clauses Act, 1847 (10 Vict. c. 17), power is given to the suppliers of water on the constant system to enter premises at reasonable hours for the purpose of seeing that there is no waste or abuse of the water, and any person committing any act by which the water is wasted becomes liable to a penalty. To this power, some of the water companies or authorities supplying the water have acquired additional provisions by private Acts giving them greater control not only over the fittings to be used, but over the repair of those found in a defective state.

Upon the power possessed over the supply and repair of apparatus and fittings reliance must be wholly placed to prevent the *third* cause of waste. It should be rigidly enforced, for in too

many instances the plumber supplying the appliances will, to save a penny or twopence in the price of a tap, adopt an inferior article, which is no sooner brought into use than it is in a constant state of leakage. At Manchester all water fittings are stamped by the authorities *before* they are fixed, and at some places not only are the fittings specified, but no one, except an authorised plumber, can repair or fix the fittings so specified. These stringent provisions are not only conducive to economy, but they are essentially just, and should therefore be enforced with strict discretion. It is manifest that the suppliers of water should be assured that the fittings, whereby the water is brought into use by their customers, should be well made and suitable.

As an illustration of the economical and beneficial effect which the exercise of legitimate powers in the hands of the suppliers of water has upon the quantity consumed, I may mention that at Norwich the consumption has been reduced from 40 to 15 gallons per head per diem, since control over private fittings (22 Vict. c. 15) was given to the company. At Manchester similar advantages have been gained by the acquisition of powers like those in force at Norwich (23 Vict. c. 93). The rules and regulations in operation at the latter town, and the general instructions as to fittings and repairs issued by the Manchester corporation, appear in the Appendix. The Appendix contains also an extract from the Water Works Clauses Acts, 1847 and 1863, as well as the regulations made under the Metropolis Water Act, 1871. Unfortunately, however, these "regulations" have been productive of little good at present. London, which should be an example to the rest of the world, is as much behind in the matter of water supply as it is in sewage disposal.

Considerable skill has been displayed by Mr. Deacon, C.E., of Liverpool, in devising a meter to be attached to a water main where waste is suspected to exist, and in associating it with observations by means of stop-cocks placed outside each house. The meter enables the inspector to see whether more than the ordinary quantity of water is being consumed in the district, and the stop-cocks enable him to discover through which houses any excess is passing. These observations are made at night when there is not much traffic, the inspectors having to judge of the waste by the sound of the water as it passes the stop-cocks. The night inspectors enter their observations in a form prepared for the purpose, and the day inspector follows up the investigation afterwards by going to the houses indicated and examining the fittings, &c. A descrip-

tion of this meter, by Mr. Bramwell, C.E., which appears to me to be applicable to any town where there exists a general water supply, is given in the Appendix.

A certain means of preventing waste is the use of a private meter in each house, in the same way that meters are now adopted for the measure of gas in nearly every dwelling where gas is consumed. There is this difference, however, between water and gas; the use of a certain quantity of the first is an essential in life, while with the other it is not. If water were paid for upon the exact quantity consumed, it is believed that a very large number of the population would reduce their consumption to a minimum that would be prejudicial to health, and result in an evil much greater than the waste of water. The idea of charging by meterage for every drop of water used in a house has therefore been abandoned, but it does not follow that the system in a modified form should not become general at no very distant date.

In applying the meter system to separate houses, it has been proposed that a certain quantity of water should be considered due to each house according to its size and its rateable value, and that the payment for that quantity should be unchangeable even though the water should not be wholly used. Beyond this certain amount the customer should have power to draw from the main any greater quantity that may be required. For this *extra quantity* —it is held—an extra payment should be made. The meter would indicate the total quantity of water consumed, and so furnish the means of ascertaining the excess to be paid for in addition to the fixed quantity. By this plan no encouragement would be given to a niggardly use of water, and the company supplying the water would thus have guaranteed to it a certain minimum income.

Fig. 107 shows in section a half-inch water meter constructed by Guest and Chrimes, of Rotherham, upon Siemens' and Adamson's patent.

This meter is constructed upon the principle of the Barker's mill. The measuring medium consists of a drum, working on an upright spindle at the bottom, and in a collar at the top. The water is conveyed by the conducting tube into the centre of the drum, and allowed to escape at three or more apertures on the periphery of the same, giving to it a rotary motion. At each revolution of the drum a certain number of cubic inches of water is delivered, so that it is only necessary to register the number of revolutions to ascertain the quantity; this is effected by wheels and pinions, and the result indicated in gallons or feet, upon a graduated dial.

Fig. 107.

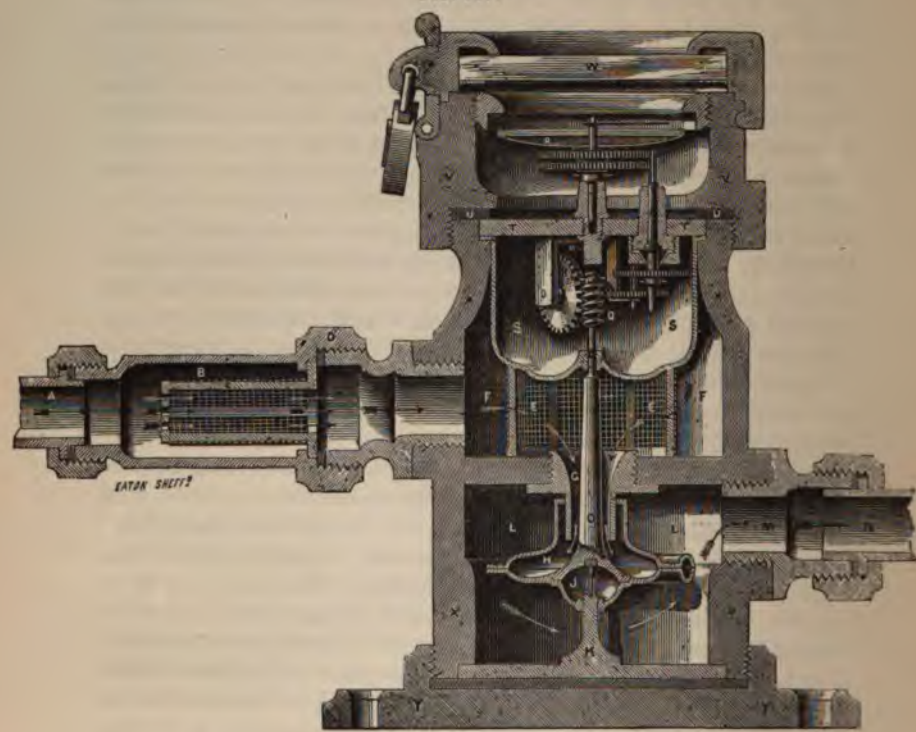


Fig. 108 represents the exterior of a water meter made by Tylor, which is well adapted to the registering of small quantities, and

Fig. 108.

is very compact in itself. The figure will serve to show the compact character of the instrument. This meter is so arranged that any repair or adjustment may be easily effected without removal. The small meters of this class are made of brass and gun-metal to avoid corrosion.

The working of these and other meters in practice is referred to in a recent paper by M. Muchall of Wiesbaden, which will be found in vol. xlvi. part iv. of the Minutes of Proceedings of the Institute of Civil Engineers.

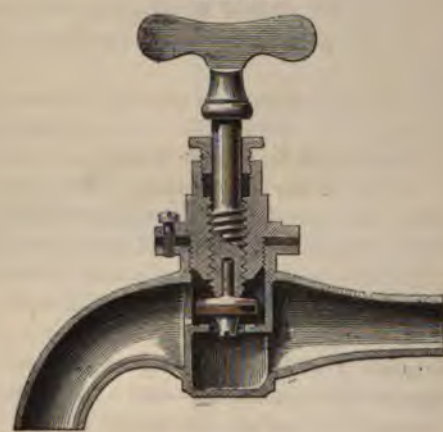
With such protective arrangements as those I have explained, it is manifestly just to the consumers that the suppliers in their turn should be made answerable in a very direct and positive manner for the quality of the water they supply. Mr. Simon stated in his evidence before the Royal Sanitary Commission, that he had "doubts if water companies—except in London—were subject to much law." There can be no sufficient reason why every source and means of water supply which can affect either communities or individuals should not be subjected to inspection and analysis, whether they be public or private property, or whether the water be consumed in large or small quantities,—and a fine imposed wherever the quality of the supply is not what it should be.

The principal fittings which facilitate the use and prevent the abuse of water consist of taps and stop valves, ball valves and special waste-preventing apparatus in connection with water-closets, stand-posts, hydrants, and other out-door contrivances. Their names, and the number of modifications which each description of article has undergone, are legion. I have already explained some of the waste-preventing arrangements which are used in connection with water-closets, and it may be well here to add to them a few examples of some of the best kinds of taps, stop-cocks, ball valves, &c.

(1.) *Taps and Stop Valves.*—The ordinary plug tap, which is familiar to every one, answers its purpose admirably where the water service is intermittent and is distributed through the medium of cisterns. Where, however, the supply is delivered at high pressure on the constant system, such a tap is quite unsuitable, as it allows the water to be shut off so suddenly as to cause a severe concussive bursting strain upon the pipes, and when the tap is only partially closed, the pressure of water behind it may at times be, and often is, sufficient to force it open and cause waste. To meet these objections, the tap known as the "screw-down" tap has been almost invariably adopted where a constant service prevails, as it can only be closed by degrees.

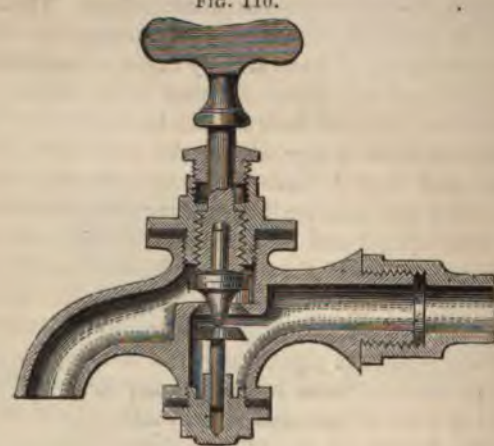
Fig. 109 represents one of these—Guest and Chrimes high-pressure screw tap. The valve of this tap is a loose valve, and is closed, as will be seen from the illustration, by being pressed upon a metal seat by means of a screw plug.

Fig. 109.



The tap shown by Fig. 110 is one of Messrs. Stone's, and its action

Fig. 110.

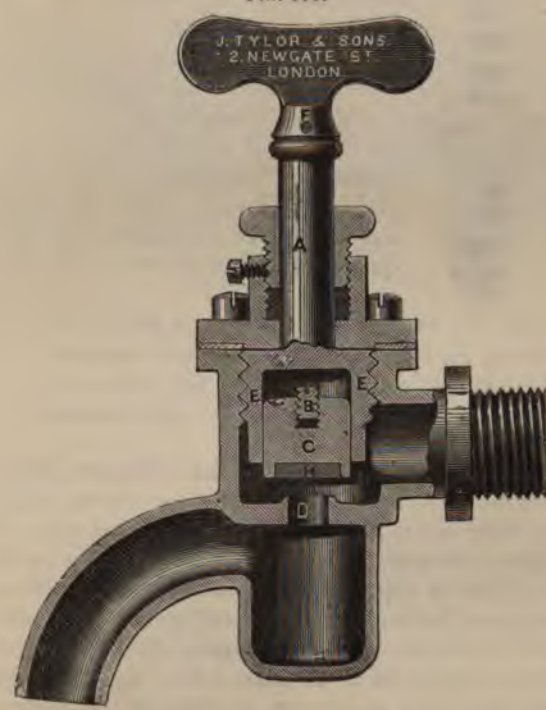


will be easily understood from the illustration. There are, it will be observed, two valves in this tap; one below and one above the seat-

ing. This arrangement allows of the repair of the upper or screw portion of the tap without in any way necessitating the cutting off of the water supply, inasmuch as when the upper valve is removed the lower one will rise, and, being pressed tightly against the seating by the force of the water behind it, stop the flow. One of Stone's screw taps is made on the same principle as the stop-cock shown by Fig. 113.

Fig. 111 represents a tap, made not only on the screw-down principle, but so constructed as to allow of the passage of only a

Fig. 111.



certain quantity of water each time the valve is opened by the screw. The tap shown is called the "screw-down, loose-valve waste-not tap" of Tylor and Sons. It is designed to prevent waste if the tap is left with the water running. This is effected by the following arrangement:

The piston regulating valve C is fitted with a washer valve H at

bottom, and moves up and down in an adjustable socket E E. The adjustable socket E E is raised or depressed by the handle F. When the handle F is turned, it raises the adjustable socket E E, which lifts with it the valve C, and opens the passage of the water through the tap. A sufficient quantity of water having been drawn, the handle F is screwed down, which depresses the adjustable socket E E, taking down with it the valve C on to the seating D. Should the handle F not be screwed down, and the tap left running, the piston valve C descends on to the seating D, partly by its gravity, but principally by the pressure of the water passing through the tap. This tap is suited for use either outside or inside dwellings, and is, I understand, exclusively adopted by the Industrial Dwellings Company.

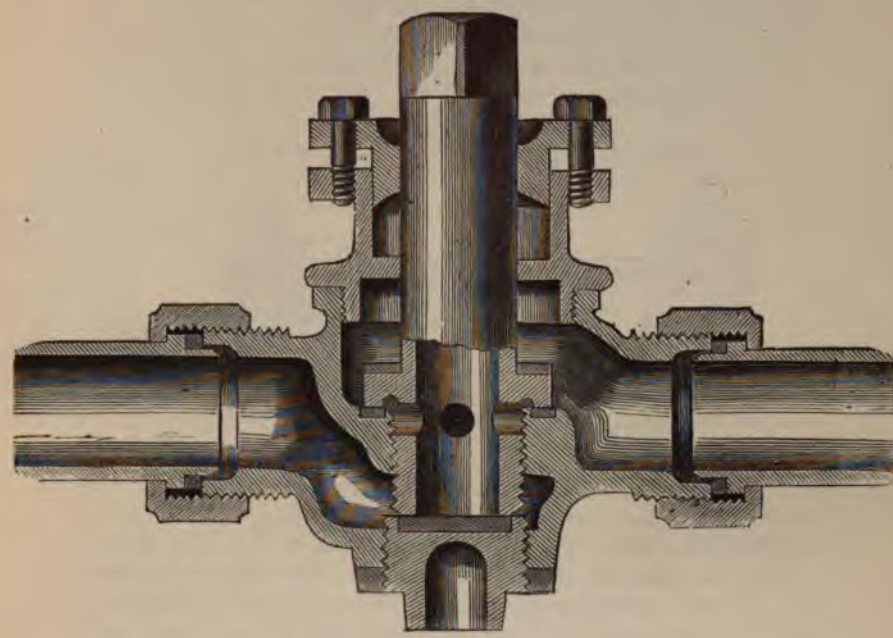
Fig. 112.

Fig. 112 shows on a small scale the self-closing screw tap of Messrs. Wallace and Connell, of Glasgow. Like the tap just described a pailful or a pint only may be drawn, but the valve will close when a regulated quantity has passed through it.

Stop-cocks are now made on the same principle as the screw-down taps first referred to. They are placed between the point at which the communicating pipe joins the main and the premises supplied, as a means of cutting off the water when necessary for repair of fittings or otherwise.

The stop-cock given in Fig. 113 is that of Messrs. Stone, to which I have just referred. In this appliance there are two valves through which the water has to pass. Both valves are cast upon one spindle and fall upon their seats at the same time. That part of the spindle which is below the upper valve is made hollow, and the end of it is faced and forms the lower valve, by resting on the flat seating at the bottom of the cock. In the illustration the direction of the flow of the water is intended to be from left to right. When the cock is opened, the hollow valve stem is lifted off the bottom, and the upper valve is lifted off its bridge seating, allowing a clear passage for the water up the hollow spindle and through ports or apertures, and thence through the upper valve. When closed, both the upper and lower valves are screwed down upon their seatings. The advantage claimed in favour of this apparatus is that should the upper valve leak, the water cannot pass the lower one; and should the lower one do so, the water can only pass up the hollow spindle as far as

FIG. 113.



the underside of the upper one. The lower valve seating is fitted in a cap screwed into the bottom of the cock so as to be capable of adjustment or renewal.

(2.) *Waste Preventers and Ball Valves.*—I have already described the several waste preventers now in use, and have now only to refer you to Section LX.

The waste which takes place in town water supplies will be found to arise as much from defective ball valves as from any other cause. Ball valves are commonly used in connection with the general service and water-closet cisterns. Where the pressure of water is great, the water itself as it enters the cistern is necessarily much agitated, and many valves are, from their construction, subject to a great amount of wear and tear from this cause. Great care should therefore be taken to select those only which by their construction limit this wear and tear to a minimum. In testing the valves themselves, not only is it necessary that they should be sufficiently strong to withstand a maximum pressure when closed, but the lever or rod should be of such a character as to act with the fall or rise

of the water in the cistern independently of any force which the water in the pipe may exercise upon the valve.

Figs. 114 and 115 are representations of the "tube" ball valve —the first being one made by Messrs. Guest and Chrimes, and the second one by Messrs. Stone and Co. The action of this kind of

Fig. 114.

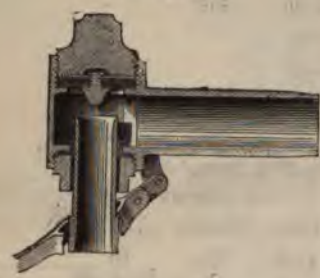
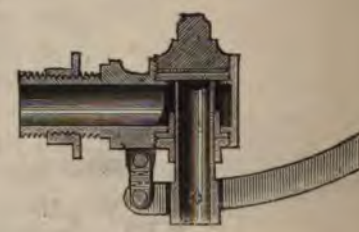


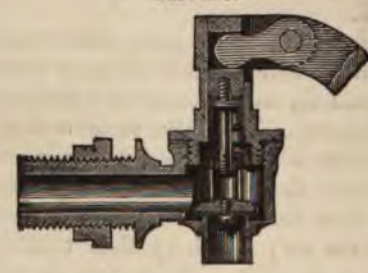
Fig. 115.



valve is very simple. The hollow tube shown in the figures is connected to the ball rod or lever, and rises or falls with the motion of the latter. When the ball rod is down, as in Fig. 114, there is a space between the top of the tube and the top of the cock. Through this space the water passes into and down the tube to the cistern or receptacle receiving it. When the ball rod is up, as in Fig. 115, the tube is pressed against an india-rubber or other seating at the top of the cock, and the passage of the water into it is prevented.

Fig. 116 illustrates a valve manufactured by the same makers

Fig. 116.



as Fig. 115, as is also that shown by Fig. 117, which represents an "equilibrium" valve.

The action of both of these valves will be understood by reference

to the figures without further explanation. That shown by Fig. 116 is more suitable where there is a high pressure of water than that shown by Fig. 117.

FIG. 117.

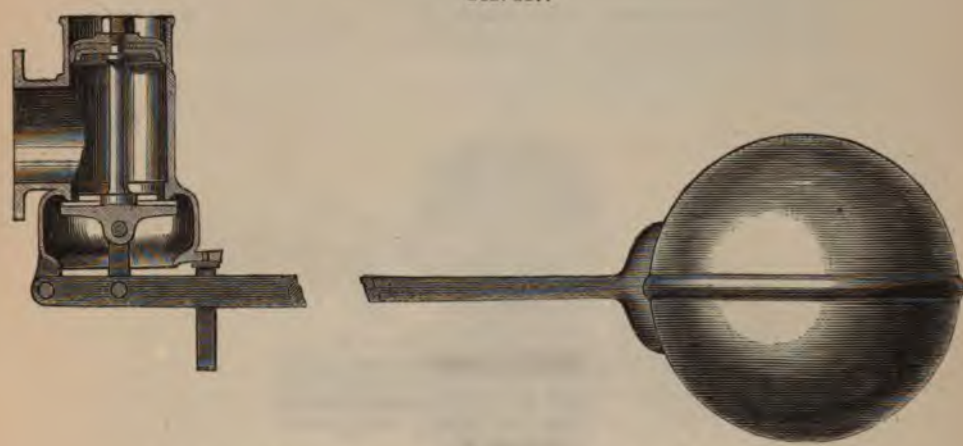


Fig. 118 shows a lever ball valve, manufactured by Messrs. Tylor and Sons, the chief feature of which is that the ball rod

FIG. 118.

is not attached to the valve, and only acts upon it when it has been raised to a certain height. In this apparatus the power exerted by the flow of water in the pipe behind the valve is withstood by the working parts of the valve immediately above, and in a line with the pin A, and not by the rod itself, which can only be raised or depressed by the rise or fall of the water in which it floats.

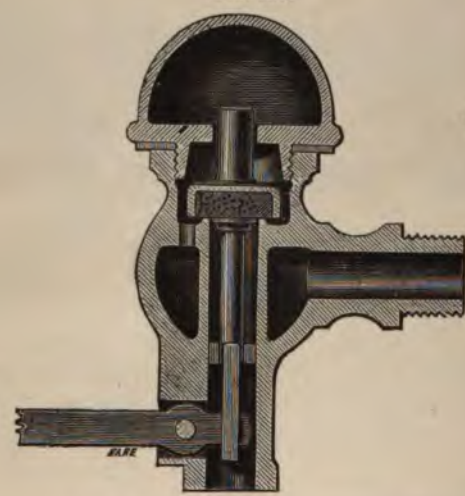
This valve possesses the advantage of confining to the ball rod

itself the jerking motion which is often given by the entry of the water and its agitation in the cistern.

Mr. Chandler of Mile End-road, London, has also constructed a ball valve which secures this latter important advantage, and which can be very readily repaired when out of order.

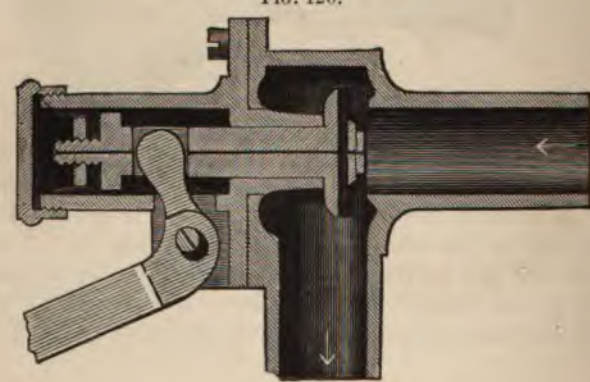
Fig. 119 represents a valve which opens upwards—the reverse of the action of the last two illustrations. It is known as the

Fig. 119.



"patent high or low pressure ball valve" of Messrs. Butler and Askie, of Southwark. When the valve is closed by the rising of

Fig. 120.



the ball rod, the pressure of the water from above assists in keeping it so until the weight of the ball reopens it. This valve appears to possess great merit.

Fig. 120 shows a valve, which unlike any of the foregoing valves, works in a horizontal direction. It is that known as the equilibrium ball valve of Underhay. The water-way of this valve continues clear until the cistern has become nearly full.

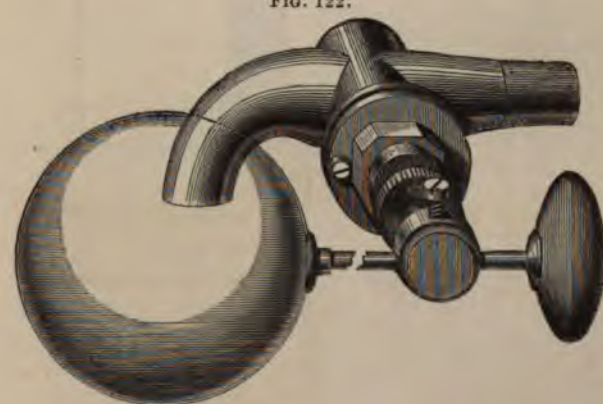
Fig. 121 represents Tylor's patent high-pressure ball valve, which has now been tried for some years with satisfactory results in con-

Fig. 121.

nection with the New River Water Company's supply. This valve also allows of the running of a full stream of water through it until the cistern is nearly filled.

There is also, besides many others, the ball valve which is made on the "loose-valve" principle. Fig. 122 shows the exterior of one

Fig. 122.



of these made by Messrs. Guest and Chrimes, of Rotherham, and Messrs. Beggs, of London. A loose valve, the face of which is

covered by a leather washer, is compressed on a prepared metallic seat by means of a screw, which is so threaded that the valve may be opened or shut with a very small fall or rise of water in the cistern.

(3.) *Stand Pipes and Water-Supply Apparatus for Courts or Villages.*—It will often happen, in rural districts, where some of the dwellings are much scattered, and where therefore the cost of laying down pipes to each house would be a veto to a good supply, that the main pipes conveying the water to the more favoured parts may be tapped at convenient places, and by means of stand-pipes, &c., be made serviceable. Care, however, must be taken to protect this description of supply from frost in winter and waste at all times.

Fig. 123.

Fig. 124.

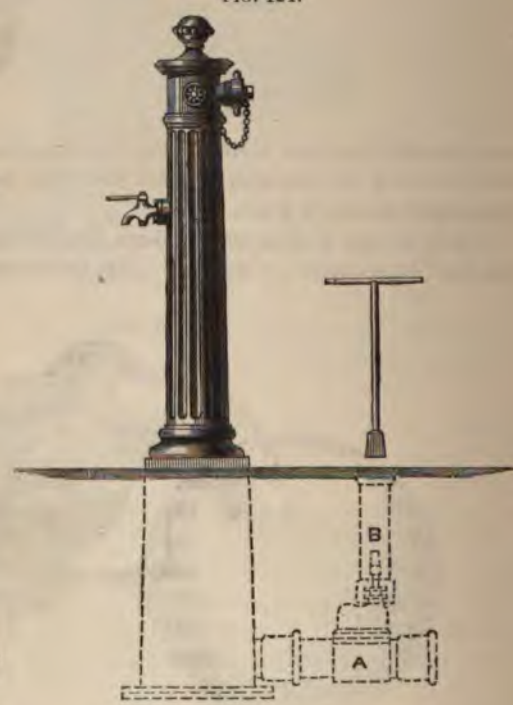
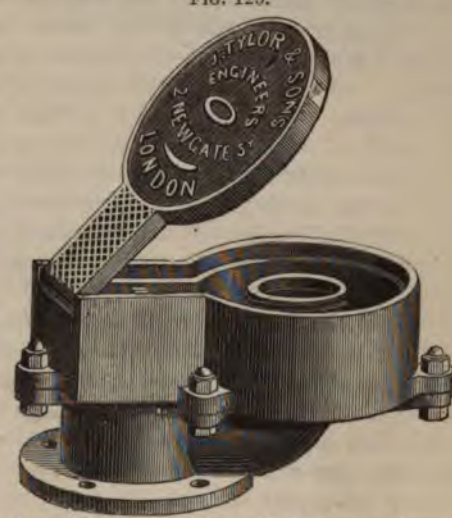


Fig. 123 shows a waste-not water post made by Tylor. This post

is fitted with a self-closing lever valve (A), which, like the tap shown by Fig. 111, will only allow a certain quantity of water to pass each time the knob is lifted—thus preventing waste.

Fig. 124 is a stand-pipe arrangement of Messrs. Warner's make, in which the supply pipe and turncock (A B) are represented at a sufficient depth below the surface to be beyond the influence of frost. This post is fitted with a cap, from which a water cart may be filled, or to which the hose may be attached in case of fire.

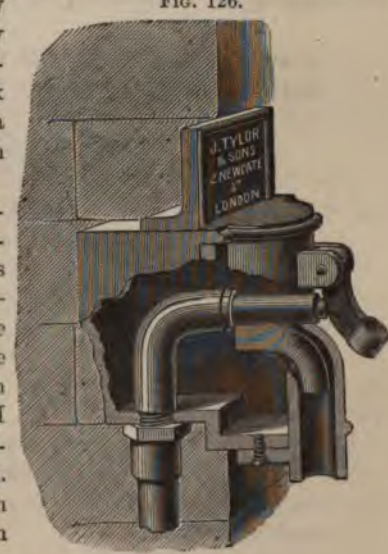
FIG. 125.



As a provision against fire a very useful hydrant called the Brighton hydrant, and shown by Fig. 125, may be placed in the footways of towns and villages in connection with water mains. It is made to fit the Brigade gauge.

Fig. 126 shows Tylor's wall box with self-closing valve—a very useful arrangement in any town or village. The supply pipe is built in the wall to protect it against frost, and the box containing the valve allows of a packing of ashes or dust, which acts as a further protection.

FIG. 126.



In the provision and distribution of water for village consumption, these several contrivances and others of a kindred kind—each in their proper place—will be worthy the careful study of the sanitary engineer. I do not wish it to be understood that those I have shown are necessarily superior to those I have omitted. There are many others which are admirable alike in design

and construction, but those shown will serve as suggestive illustrations of the different kinds of apparatus now in use.

Although in my prefatory remarks in this section, I referred you back to what I had previously said as to the sources of water supply available for small towns and villages as well as the dwelling, and the means by which that water can be raised and distributed, I cannot close my observations without reiterating the conviction I entertain that if this important object were investigated by practical men as suggested in Section XLI., a means would be found of supplying the various small communities scattered over the country, which are now without a proper supply, with water of an unexceptionable character in the place of the "dangerous waters" of surface streams and shallow wells (see Division II.). It would then be found that it could be generally done at a cost not exceeding that prescribed by the Public Health Act (section 62), *i.e.*, 2d. per week per house for all small tenements, assuming that a higher rate of charge—which would be willingly paid—were made on houses of a greater rateable value than 10*l.* per house. For instance, a village containing 200 dwellings of all sorts, half of which were below and half above 10*l.* a year rateable value, might readily raise the sum of 173*l.* 6s., and this would cover an annual charge, say, of 72*l.* a year to repay an outlay of 1200*l.* in procuring the supply by a deep well from a water-bearing stratum, and 100*l.* a year for pumping and distributing it: thus,

			£	s.	d.
100 × 2d. per week =	16s. 8d. × 52 weeks =		43	6	8
100 × 6d. „ =	2*l.* 10s. 0d. × 52 „ =		130	0	0
			173	6	8

I give these figures more as an illustration of what I believe may be often achieved in any district overlying the chalk, the oolite, or the new red sandstone, than as positive data.

LXXXIX.—Concluding Remarks on the Sanitation of Towns and Villages. Having dwelt in some detail upon the duties of the sanitary engineer in relation to towns and villages, I will shortly epitomise the principal objects in which, I consider, all sanitarians should concur.

(1.) To maintain *pure air* throughout all inhabited parts of either urban or rural districts they should be *sewered* for the discharge of the foul liquid refuse of dwellings, and *drained* for the discharge of ground water.

(2.) A sufficient quantity of unexceptionally *pure water* should be supplied to all communities either by private or public works.

(3.) All sewers should be water-tight, first to prevent the pollution of wells, and next to protect the soil and foundations of houses from excremental saturation.

(4.) No sewers, under any pretence, should be jointed with clay where the water used in a town or village is derived from "shallow" wells.

(5.) No wells for the supply of water used for domestic purposes should be allowed to exist within 100 feet of any sewer, let the mode of jointing be what it may.

(6.) No cesspits for the reception of excretal matter which are not perfectly water-tight should exist in the inhabited parts of any district, and, if water-tight, only when systematic scavenging is strictly carried out by the local authority. Special attention should be given to slaughter-houses and noxious trades.

(7.) All sewers should be periodically cleansed by flushing where they are not perfectly self-cleansing.

(8.) All sewers should be ventilated by inlets and outlets at sufficient intervals to secure the perfect influx of pure air, and the efflux of foul air throughout the entire system. Artificial expedients for deodorisation, such as charcoal trays, &c., should only be resorted to when this natural mode of treatment is inapplicable.

(9.) As a rule, surface water should be excluded from town sewers as far as practicable, though exceptions may not unfrequently be recognised.

(10.) As a town or village is only a congregation of dwellings, all urban or rural authorities should have sufficient, though it may be limited, control over the sanitary arrangements of every dwelling constituting the town or the village to secure conformity with recognised regulations.

(11.) To secure the best results from sanitary works the overcrowding of dwellings must be prevented.

(12.) Scavenging is as essential in villages as in towns, and neither the one nor the other should exist without a carefully devised system of scavenging with special reference to noxious trades and offensive collections of putrescible matters.

DIVISION V.

THE TREATMENT AND DISPOSAL OF LIQUID SEWAGE.

XC.—Prefatory Observations. We have now arrived at the treatment and disposal of the liquid sewage of sewers which sanitary engineers have, until recently, done their best to remove from towns into rivers in obedience to legislative requirements, but which under the altered state of the law they now must abstain from so discharging until it has been freed from all "foul or noxious matters" by "the best practicable and reasonably available means."

It is not necessary again to refer to that portion of sewage which consists of the solid refuse of habitations and which it is the duty of the scavenger to remove. The refuse of which I am about to speak is the foul liquid which, having been admitted into the sewers, must necessarily find its way in some condition or other into the river, or stream, forming the natural outfall of the district.

I have already said that the towns of this country may be divided into three classes, according to the outfall they command (see Section LXXX.), and, with respect to their sewage, that the degree of purification to be aimed at before the effluent sewage-water can be ultimately discharged, may in each class be different. If this view be correct many modes of effecting the necessary purification may be examined, and the special claims of each for economy and suitability considered and compared with a view to adoption, where appropriate.

One certain result of the experiences gained since the passing of the first Public Health Act in 1848 (11 and 12 Vict. cap. 63) is that a very large majority of the people of this and other countries—I refer to those who have given their attention to sanitary matters—are convinced that, however suitable chemical precipitation may be as a means of treating sewage in special cases, recourse to *land*—where land in a greater or less extent is to be obtained—is the best means

by which the liquid sewage of inland towns can be permanently freed from "foul or noxious matters."

The instinct of the cat in covering its fæces with earth—the rule of the Egyptians that they should "cover that which cometh from them with earth" (Deut. chap. xxiii. v. 13)—and the satisfactory results obtained in recent years from the use of dry earth in the closet, definitively point to the superior property of natural soil as a *deodoriser*. (See Section CI.)

The analyses of Dr. Frankland, Dr. Russell, Dr. B. Paul, and Mr. Dyke, of the effluent water issuing from the 6 feet deep drains of the filtration areas at Merthyr, show conclusively the extraordinary power of natural soil as a *cleanser* of filthy liquid if it is passed through it *intermittently*.

The remarkable growth of vegetation from soil to which such filthy liquid is applied, demonstrates its power as an *utiliser* of sewage with equal certainty, and shows that a *return*, capable of increase with advancing knowledge, is to be obtained from the application of sewage to land under good management and with a proper regard to local markets. (See Section CII.)

And the fact that, while tanks and other structures of masonry required for the mechanical deposition and the chemical precipitation of the suspended substances of sewage are liable to gradual decay and reduction in value, land not only maintains its value, but *increases* therein every year—irrespective of the use to which it is turned,—is in itself an advantage in favour of land which may fairly go some way to reconcile sanitary authorities to the use of it. This increase on an average amounts to one per cent. per annum. Experience has taught us that no rule can be laid down as to the character of land that can be best utilised or its position relatively to the town supplying the sewage,—whether it would necessarily be better to discharge it on to low valley lands* by gravitation or to lift it on to hills by pumping. There is much to be said on these points.

What we have not learned, and have yet to learn, and which we hope the coming report of Mr. Sclater-Booth's Committee will teach us, is (1) the *extent* to which it is advisable to apply sewage to land, (2) under what circumstances the *area should be increased or diminished*, and (3) by what mode of treatment the application of sewage to land *may be made profitable* to the sewage farmer. The experience of the last few years has, fortunately for the rate-

* See evidence before the Royal Commission on Water Supply, Question 1613 *et seq.*

payer, shown that a very small superficial extent of suitable land, if deeply drained and properly prepared, will suffice for purification (see Sections LV. and CI.), while unfortunately for agriculture it has also been shown that the greater the width of area over which the sewage is spread in excess of that required for its purification, the greater is the loss to those who venture on sewage farming. (See Section XCII.) This latter statement, like all general statements, is of course subject to modification, and it is to the way in which modification may facilitate the profitable use of land that sanitary authorities and sanitary engineers should give their particular attention.

Where, for instance, there exists a sure and increasing market for sewage-grown produce, consisting of succulent grasses and vegetables, or where the population of the district consists largely of miners and factory hands, who will soon create a market if it does not exist, great encouragement to extend the application of sewage is given; and where land can be purchased at a moderate price, or leased for a long period at a moderate rent, the area may be discreetly increased with every confidence that as practice makes perfect it will not be long before profit will overtake loss. Progress in the utilisation of sewage, however, is very slow, and in anticipation of the promised report of Messrs. Rawlinson and Read on this most important matter, it will be my object to show you how by observing the rules of common prudence, and by having a proper regard to the cost of land, the suitability of soil, and the proper cultivation of the surface, sanitary authorities may to a very great extent relieve themselves of the hesitation which now prevails amongst them. I shall enter upon the duty I have prescribed for myself with the acknowledgment that although land is pre-eminently the proper medium for cleansing and utilising sewage, it is opposed to sound national economy to make the present generation of ratepayers suffer a loss in the purchase and cultivation of land in order that the next may realise a return. As money will double itself in less than twenty years at an ordinary rate of compound interest, and the practice of the last twenty years has failed to show that any profit at all is to be obtained from sewage farming, it is manifestly more prudent to defer as long as possible the purchase of any land in excess of that which will *cleanse* sewage and so meet the requirements of the Legislature, than to launch into a large expenditure in land on the supposition that we shall soon discover the golden way to profit.

Whatever may be the chemical value of sewage, it appears manifest to those who must have regard to the commercial view of the matter, (1) that with present knowledge, unless land of a suitable character can be obtained by purchase, or on a long lease, at a charge not exceeding 2*l.* 10s. per acre, no sanitary authority is justified in securing any very large extent of area; (2) that if land can only be obtained at a price or at a rent above 2*l.* 10s. per acre, but not exceeding 5*l.*, or say 7*l.*, an acre, then the authorities may fairly secure a medium quantity (regulated by local markets and the means of effecting a ready sale of sewage produce) of, say, one acre to 300 or 400 of the present population; and (3) that if the charge to repay the purchase money of the required land exceeds 10*l.* an acre, then there ought to be no hesitation in reducing the area to the least quantity that will suffice to cleanse permanently the sewage which may be taken to be one acre to 1000 persons of the prospective population. It is to be quite understood that these figures of area are based on the assumption that the land is suitable, that it is properly drained and prepared, and that it is properly treated afterwards by intermittency of application.

Although these conclusions are forced upon sanitary authorities by the experiences of the last twenty years, it behoves us all, as good citizens, to do nothing that shall *prevent* the full development of the reproductive properties of the refuse of our towns and villages at a future time with increased knowledge.

We must not discard the teachings of chemistry, though we must be most careful not to be misled by them. With the population of Great Britain doubling itself in less than fifty years, it is our duty to remember that Boussingault has laid it down, if I remember the figures rightly, that an adult gives off in his excrements as much as 16·41 lb. of nitrogen yearly, which is a quantity sufficient to yield 800 lb. of wheat and 900 lb. of barley, while Liebig goes so far as to say that each unit of the population can, on an average, supply, with the nitrogen absorbed from the atmosphere, sufficient manurial matter to raise from an acre of ground the "richest possible crop every year." The question that follows is, How? Without aiming at such extreme returns I hope to assist in some degree in answering this question by showing that with proper arrangements the sewage farmer may be master of his own proceedings, which at present he is not.

XCI.—The Character of the Sewage discharged by Sewers of Towns and Villages of different Characters. Before entering

upon the different modes of treating sewage, which I would designate *artificial* treatments, and which may possibly be advantageously adopted in one class of towns or another where land cannot be obtained, it is desirable to point out that, although the social habits of populations differ very considerably, yet the sewage discharged from towns in which no special trades exist is almost always the same in its distinguishing qualities.

These qualities are indicated by (1) the amount of soluble matters of manurial value contained in the sewage, measured by the combined nitrogen; (2) the amount of soluble matters of a polluting nature which are not of manurial value, and which may possibly detract from the value of the sewage;* and (3) the amount of insoluble suspended matters which may be separated from the liquid by subsidence or precipitation.

The similarity in sewage of which I have spoken, is found to prevail in all towns alike, whether the excrementitious refuse of dwellings be admitted into the sewers, or whether it be collected separately and removed by the scavenger. Towns under these distinguishing conditions are severally designated "water-closet towns" and "midden towns," the latter including towns and villages in the southern part of England in which privies are used, and in which the word "midden" is unknown, as well as those in the northern counties where "midden" is the common term for "privy." The following chemical analyses of the Rivers Pollution Commissioners will show the precise characters of sewage discharged from water-closet towns and midden towns.

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* Speaking at a meeting of the Society of Arts, December 8, 1871, Dr. Frankland, F.R.S., said he "thought the paper failed to distinguish between two separate things, the purification of sewage water, and the extracting from it the manurial ingredients. These two subjects were very frequently confounded. You might purify sewage by transforming its polluting into non-polluting ingredients, so that it might be admissible into any stream without the possibility of creating any nuisance, and not extract from it one particle of its manure value . . . On the other hand, it was also possible to extract certain manurial constituents from the sewage without completely purifying it, and by the aid of plants and soil you could also extract the valuable constituents from the sewage, and store them up in the tissues of the plants to a considerable amount, still leaving a considerable portion of valuable though non-polluting particles in the effluent water. This was what had been accomplished at Merthyr, as he could testify from an examination of the works and the effluent water. The effluent water was so pure that if it contained twice the percentage of impurities which it did, it would still fall considerably within the standards of the Rivers Pollution Commissioners. Many persons drank it, though that was no criterion, for he had seen people drink slightly clarified sewage with avidity, and declare it was excellent . . . Waste went on upon sewage farms" (on the wide principle) "almost everywhere to an extent not at all appreciated by those who were applying the irrigation process. It was no uncommon thing to find a quarter or half, nay, in some cases, seven-tenths of the fertilising constituents of the sewage going away in the effluent water, even on the most successful sewage farms. They might, therefore, look forward to getting a much larger amount of produce out of a given quantity of sewage than had yet been obtained."

Description.	In 100,000 Parts.									
	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral.	Organic.	Total.
WATER-CLOSET TOWNS:										
London, Feb. 23, 1869...	66·5	5·137	2·375	6·050	0	7·357	...	15·48	18·84	34·32
,, June 23, 1869..	65·3	2·596	1·715	4.000	0	5·010	8·6	18·48	27·80	46·28
Leicester.....	107·5	2·017	·809	2.083	0	2·524	...	10·50	11·62	22·12
Croydon.....	41·2	2·565	1·134	3·635	0	4·128	4·0	·84	4·10	4·94
Bedford	76·1	2·256	1·301	3·100	0	3·854	10 9	8·16	13·68	21·84
Leamington	83·5	4·355	2·890	5·971	0	7·807	11·0	96·24	56·28	152·52
MIDDEN TOWNS:										
Manchester.....	62·0	2·215	1·516	·380	0	1.829	...	23·18	11·22	34·40
Macclesfield	47·6	2·874	1·046	1·739	0	2·471	9·0	4·72	5·44	10·16
Bolton	42·0	2·985	1·843	6·430	0	7·138	...	6·78	14·58	21·36
Blackburn	72·6	4·834	1·088	3·475	0	3·950	8·3	9·24	16·16	25·40
Chorley...	71·2	4·968	1·495	3.492	0	4·371	10·6	11·84	19·24	31·08
Edinburgh	62·2	6·106	3·613	9·510	0	11·445	13·3	11·32	28·08	39·40

The Commissioners when giving these figures state:

"These analytical numbers show a remarkable similarity of comparison between the sewage of midden towns and that of water-closet towns. The proportion of putrescible organic matter in solution in the former is but slightly less than in the latter, whilst the organic matter in suspension is somewhat greater in midden than in water-closet sewage. For agricultural purposes 10 tons of average water-closet sewage may, in round numbers, be taken to be equal to 12 tons of average privy sewage. The average quantity of chlorine in 100,000 parts of water-closet sewage is 10·66, while in midden sewage it is 11·54. This difference is very significant; it shows that, assuming (which is probably approximately the case) all the urine to reach the sewers in both classes of towns, a larger number of individuals contribute to a given volume of sewage in midden than in water-closet towns. Chlorine, in these cases, represents common salt, and the latter again indicates the proportion of urine in the sewage. The proportion of chlorine, therefore, ought to give the proportion of average individuals (men, women, and children) contributing to each kind of sewage; and from this it would follow that the population producing equal volumes of sewage in midden and water-closet towns are as follows:

In water-closet towns	1,066
In midden towns	1,154

The cause of this difference in the volume of sewage per head of population in the two classes of towns is obviously to be sought for in the somewhat increased quantity of water needed by and supplied to the former."

With respect to the sewage of water-closet towns, Messrs. Lawes and Gilbert in their Report on the Sewage of Rugby (which town they took as a fair sample of the class) stated, that having regard to the average result of 93 analyses, they found that the sewage contained about 87½ grains of total solid matter per gallon (70,000 grains), of which about two-thirds was inorganic, and one-third organic. About half the total solid matter was in suspension, and half in solution. Of the half in suspension, about four-sevenths was inorganic, and three-sevenths organic, and of the half in solution about four-fifths was inorganic, and one-fifth organic.

Having previously pointed out (see Section LXXV.) that the liquid refuse from manufacturing works may alter the character and value of sewage if admitted into sewers, it may be useful here to give in similar terms to the foregoing analyses the constituents of the refuse liquid discharged from trades of different characters which I have compiled from the reports of the Rivers Pollution Commissioners.

In many of the smaller towns of an ordinary character in the agricultural counties of England, possessing no special class of trades to characterise the sewage, the outflow from certain premises, such as a tannery or a brewery, will greatly affect the sewage of the portions of the district lying immediately below them, and cause an uprising of effluvium from particular shafts in the streets which serve for the ventilation of the sewers.

I need hardly remark that the chemical analyses of the liquid refuse of towns and trades given in this section do not cover the coarser solid matters which are generally separated from outflowing sewage by straining arrangements. These are necessarily excluded from the samples of sewage analysed by chemists, because they are too bulky for collection in the sample bottles used for analyses. Though the average weight of these coarser ingredients per gallon of liquid sewage is small, there are some towns in which the aggregate weight is sufficient to necessitate special treatment at the mouth of the sewer.

Nor do they include the heavier solid road and mineral deposits which fall to the bottom of tanks after passing through a screen;—but include simply those matters which in the words of the chemist are "suspended." (See Section XCIII.)

COMPOSITION of the Refuse Liquids discharged from Trades of different Characters.

DESCRIPTION.	IN PARTS PER 100,000.										
	Dissolved Matters.								Suspended Matters.		
	Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Metallic Arsenic.	Chlorine.	Mineral.	Organic.	Total.
Rivers Pollution Commissioners standard of admissible waters	...	2·00	·30	...	...	...	·050	...	3·0	1·0	
Woollen and Cotton Mills—Waste liquors from, mixed with town sewage (average of 15 samples)	337,0	64·78	10·38	11·65	·041	20·01	·011	21·94	102·4	372·4	474·84
Woollen Mill—Waste liquor from indigo-extraction process, as discharged into stream near Nailsworth	363·0	59·05	14·38	2·48	0	16·42	0	10·00	·8	·4	1·25
Do.—Liquor entering Avon from grease extraction process	307·7	23·51	10·81	15·47	0	23·55	·080	21·40	·5	5·7	6·16
Do.—Waste woollen dye liquor	204·7	43·20	2·72	2·34	0	4·65	0	14·40	1·8	25·3	27·08
Blanket Mill, Witney, Discharge therefrom.	678·0	120·71	19·51	·94	0	20·28	·004	35·60	60·4	314·2	374·60
Flannel Mill—Waste liquor as discharged into Severn	1248·0	446·35	91·18	80·01	0	157·08	0	160·00	346·0	1733·4	2079·4
Carpet Works—Dye-vat liquor as discharged into river	460·9	129·34	2·86	4·85	0	6·85	0	...	36·4	100·5	136·9
Cotton Dye, Print, & Bleach Works—Discharge therefrom	50·2	4·22	·30	·12	0	·40	·034	4·86	7·0	19·0	26·0
Dye Works—Waste liquors therefrom after subsidence	70·5	3·29	·34	·28	·06	·63	0	6·60	3·6	3·6	7·2
Silk Print Works	26·5	1·49	·15	·03	...	·17	·012	...	...	...	...
Paper Mill—Esparto liquor	4038·0	938·84	76·81	1·12	...	77·73	0	58·00	...	...	...
Tanneries—Spent tan liquor	8459·0	3182·17	36·29	10·83	...	45·21	...	...	...	...	...
Do.—Spent lime liquor	3186·5	205·94	53·41	25·80	...	74·66	...	...	...	...	...
Do.—Liquor as discharged from a tan-yard sewer	848·0	79·48	5·37	5·18	...	9·64	...	...	...	...	...
Alkali Works—Sewage and waste products therefrom	1890·0	20·50	·75	·64	·024	1·31	1·500	699·30	...	...	30·96
Soap & Alkali Works—Discharge of united sewers	325·75	...	...	Murtc acid. 588·20	·123		·200	637·88			
		3·04	2·67	...	2·200	8·291	·012	1075·00	17·76	16·28	34·00
Galvanising Works—Effluent therefrom	1986·0	Sulph. acid. 323·86				Acidity as muriatic acid. 1329·30	Metallic iron. 698·81				
German Silver Works—Waste liquor	3541·8	20637·4	Hydrchlric acid. 262·3	...	Metallic zinc. 2·57	15416·0	Metllic copper. 90·88	Nitric acid. 246·62	Turbid		
Brass & Copper Tube Factory—Waste liquor	32161·0	17474·0	...	...	1280·6	15792·0	15·96		Very turbid.		

XCII.—The Value of Liquid Sewage. Messrs. Lawes and Gilbert, in the analyses to which reference has just been made, stated that of the nitrogen existing in sewage about one-fourth was in suspension and three-fourths in solution. The mean of 93 analyses showed that the quantity of nitrogen per gallon was equal to about 6½ grains of ammonia, indicating a value of 1⅔d. for the total constituents of one ton of sewage. Multiplying these figures by the 60 tons of sewage per head per annum due to each contributing individual (25 gallons + 50 per cent. for subsoil-water influx, × 365 days ÷ 224 gallons), it will be seen that 12½ lbs. of ammonia (value 8d. per pound) is contributed annually by each individual of a mixed population of both sexes and all ages, and that therefore 8s. 4d. represents the chemist's value of sewage per head for water-closet towns.

Various other estimates have been made.

Dr. Letheby took samples at noon and at midnight from a number of sewers in the metropolis, and arrived at the conclusion that 7.24 grains represented the mean quantity of ammonia per gallon.

Messrs. Hofmann and Witt considered that 8.21 grains per gallon represented the correct quantity. These figures would, if taken at the same price for ammonia, give larger results than those of Messrs. Lawes and Gilbert.

Messrs. Hofmann and Witt and Dr. Thudichum together gave an estimate of another character. Having ascertained the amount of urine and fæces voided by individuals—the average of both sexes and all ages—they valued the urine at 7s. 3d., and the fæcal matter at 1s. 2¾d., which, although consisting only of excrement refuse, gave very nearly the same value as that put by Messrs. Lawes and Gilbert upon the whole sewage of the sewers, containing, besides human excrement, the slops and other household refuse. In the comparison made of the analyses of the sewage of midden towns (where much of the excrement refuse is removed by the scavenger), and of water-closet towns (where the same is admitted into the sewers), you will remember that there was shown to exist very little difference between the two. It is difficult, therefore, to reconcile these figures. One striking feature in the estimate quoted is, that the urine of human beings, which is often wantonly wasted without any pretence at collection, is valued for the ammonia it contains at about six times as much as the fæces. This is based on the fact that the quantity of ammonia in the urine of an adult male person amounts to 11·32 lb. per annum, while that in the fæces amounts to only 1·64 lb.

These figures differ somewhat from those set forth by Dr.

Voelcker, in his essay on the value of earth closet manure (see the *Journal of the Royal Agricultural Society of England*, Second Series, vol. viii.) In that essay he says: "On calculating the amount of ammonia which will be produced on the decomposition of the dry matter of the solid and liquid excrements of each person per annum, we obtain from the

	Ammonia.
23 lbs. of dry matter contained in the solid excreta	1·60 lbs.
And in 34 lbs. of dry matter contained in the liquid excreta . . .	8·12 „
Or altogether	9·72 „

In other words, five-sixths of the ammonia capable of being generated on the decomposition of human excreta is furnished by the urine. By a similar calculation I find that, according to the preceding data, each individual would furnish about 5½ lbs. of phosphates per annum. For simplicity's sake we may assume that each person of a population produces in the solid and liquid excreta 56 lbs. of dry matter per annum. These 56 lbs. produce in round numbers 10 lbs. of ammonia and 5½ lbs. of phosphates."

Dr. Voelcker by taking the value of the ammonia at 9d. per pound, and the phosphates at 2d. per pound, found the total value of excreta per head, per annum, to be 9s.

When tested by the price actually put upon average sewage by persons proposing to purchase or use it, the figures altogether fail to convey to the mind any tangible indication of the money to be made of it. They indicate nevertheless the immense value of the sewage lost to the country; for if only half the estimate of Messrs. Lawes and Gilbert could be obtained for the liquid refuse of the present population of England and Wales, the money value of this reproductive article would amount to nearly 5,000,000*l.* sterling per annum. Present population 23 millions × 4s. 2d. = 4,791,666*l.*

There exists, in fact, no tangible evidence of the money (renting) value of sewage in bulk, and by itself, as recognised by farmers and gardeners. The prices which in certain cases have been paid vary exceedingly. Lord Warwick pays the authorities of Leamington 450*l.* a year for the sewage of their town, after it has been delivered at their expense. Mr. Brundell leases the sewage of Doncaster, with 263 acres of land, of which a part only is laid out for irrigation, at 800*l.* a year, and in this case, too, the sewage is lifted at the expense

of the town. Mr. Hope, V.C., leased the sewage of Romford, also pumped and delivered by the town, together with 119 A. 2 R. 1 P. of land for the sum of 900*l.* a year, but this agreement being terminated only conveys the lessee's original estimate of the value of the farm with the sewage. At Cheltenham the sewage, together with the land to which it is applied, is let for about 6*l.* an acre. At Epsom the sewage is let with a farm of 327 acres (60 acres of which only are irrigated) at 600*l.* a year, the town authorities being at the expense of pumping and distributing the sewage. The sewage of Wrexham, with 84 acres of superior land, is let to Lieutenant-Colonel Jones, V.C., at a rent of 350*l.* a year,—the land itself without the sewage being probably worth nearly all the money.

It will be observed that, with the exception of the first instance, the figures given cover land as well as sewage, and as they are based upon circumstances special to each case, they afford no accurate data from which to ascertain the commercial value of sewage alone. It is true that some small part of the Cheltenham sewage is sold to neighbouring farmers at 7s. 6d. a dressing an acre, and that some of the Leamington sewage is also disposed of at as high a price as 20s. to 30s. an acre, but inasmuch as the sewage in each case is only taken when it is desired, and in the quantity agreed upon, these purchases prove no more than that *there would be a price given for sewage if it were not compulsory to take it at all times*, and that it should be an object with all sanitary authorities so to arrange the disposal of their sewage that they can let it with or without land, at the option of their customers.

One thing is manifest, and that is, that to dispose of sewage the authorities of all districts, where it will not gravitate to suitable land without the help of steam or water power, must take upon themselves the expense of pumping as a part of the sewerage system. Pumping cannot be regarded as an item to be recovered by farming. Indeed, it is a question whether the land should be charged with the cost of delivering the sewage by internal branch conduits to the different parts of the farm over which it is distributed, some lands being very irregular in shape, and requiring considerable outlay to deliver the sewage to the various summits within the farms, while others require but little. My own opinion distinctly is, that no sanitary authority ought at present to expect a greater rent from land and sewage together than 6*l.* an acre, although in exceptional cases an authority may obtain a profit from farming themselves and so realise a higher return.

This is made evident to the practical man by the fact that

although enormous crops* have been frequently grown, and the money realised from them has been very great, and may very fairly be put forward as proof of the great productive powers of sewage, and although every one admits that there exists in liquid sewage a value which is not confined to its manurial elements, but extends to the water by which those elements are conveyed, yet so many drawbacks are experienced in the utilisation of sewage, and so little has been done to get rid of them by reference to facts in place of opinions, that we find ourselves as much at sea now as we were twenty years back as to the best way of setting to work to obtain the best returns. It is to be hoped that the Committee appointed by the Government will supply the information so much wanted.

To show the real commercial effect of applying town sewage to land, it is necessary to see how its disposal affects the ratepayer's pocket, and having asserted that which will be generally conceded—that the ratepayers of all districts must take upon themselves not only the work of sewerage and drainage, but the delivery of the sewage at a point where it may be treated and disposed of—I will now content myself with presenting in a tabular form (see next page) the information I can convey. It is limited to half a dozen instances.

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* The following crops (maxima) have been raised by sewage farming and sold at the prices stated.

Description of Crop.	Year of Production.	Place.	Value of Crop per Acre. £	s.	d.
Italian rye grass ...	1868	Norwood	22	0	0
	1869	Lodge Farm, Barking	25	0	0
	,,	Norwood	25	0	0
	,,	Edinburgh	32	0	0
	1870	Lodge Farm, Barking	37	0	0
	1871	Do. do.	22	0	0
	,,	Warwick	12	14	0
	,,	Banbury	13	16	10
Mangolds.	1870	Lodge Farm, Barking	32	0	0
	1871	Do. do.	44	0	0
	,,	Warwick	26	5	0
	,,	Rugby	21	9	0
Swedes ...	1871	Warwick	26	5	0
	,,	Rugby	18	15	0
	,,	Banbury	14	6	8
Carrots ...	1869	Lodge Farm, Barking	38	0	0
	1870	Do. do.	45	0	0
	1871	Rugby	45	0	0
	,,	Warwick	35	0	0
Parsnips .	1868	Lodge Farm, Barking	35	0	0
	1870	Do. do.	35	0	0
	1871	Do. do.	52	0	0
	,,	Warwick	35	0	0
Cabbages .	1868	Lodge Farm, Barking	35	0	0
	1870	Do. do.	15	0	0
	1871	Do. do,	24	0	0
	,,	Banbury	21	11	6
	,,	Warwick	35	0	0
	,,	Rugby	15	0	0
	,,	Merthyr	20	0	0
Potatoes	1869	Lodge Farm, Barking	33	0	0
	1870	Do. do.	25	0	0
	1871	Do. do.	18	0	0
Onions ...	1869	Lodge Farm, Barking	38	0	0
	1870	Do. do.	62	0	0
	1871	Do. do.	104	0	0
	,,	Warwick	35	0	0

TABLE SHOWING THE MONEY RESULTS OF THE APPLICATION OF SEWAGE TO LAND.

NAME OF TOWN.	Population.	Rateable Value.	Treatment of Sewage.	Acreage of Farm to which the Sewage is applied.	Purchase Money or Rent of Farm.			Preparation of Land.		Total Cost of Land and Preparation, and Annual Charge to Repay the Same.		Money Results of Sewage Treatment.			Difference between Balance of Receipts over Expenditure on Farm and Annual Charge to Repay Outlay on Land and Preparation—i.e. Annual Sum to be charged on Ratepayers.	Charge upon Ratepayers.	
					Cost where purchased by Sanitary Authority.		Yearly Rent where Leased by Sanitary Authority.	Outlay by the Authority.	Yearly Instalment to repay Principal Money and Interest in 30 Years. (6 per cent.)	Total Outlay.	Yearly Instalment to repay Principal Money with Interest in 30 Years, including Rent where Land is Leased. (6 per cent.).	Amount received by Sanitary Authority where Land and Sewage are let together.	Excess of Receipts over Expenditure (exclusive of Rent) where Land and Sewage are dealt with by Sanitary Authority themselves.				
					Price.	Yearly Instalment to repay Principal and Interest in 30 Years. (6 per cent.)							Total.	Per Acre.		Per Person.	Per Pound of Rateable Value.
		£		acres.	£	£	£	£	£	£	£	£	£	£ s. d.	£	£ s. d.	£ s. d.
SEWAGE DELIVERED BY GRAVITATION AND LAND LEASED FOR LIMITED PERIOD ONLY.																	
Wrexham	9,000	31,000	Irrigation	84	...	...	320	estimated at 500 at least.	30	...	...	350	...	...	nil	nil	nil
N.B.—Land yet to purchase.																	
SEWAGE DELIVERED BY GRAVITATION AND LAND PURCHASED OUTRIGHT.																	
Tunbridge Wells	20,000	140,000	Irrigation.	285	...		...	...	...	87,000	5220	...	528	1 17 0¼	4692	0 4 8	0 0 8
Wolverhampton	70,000	208,000	Irrigation.	248	32,000	1920	...	6000	360	38,000	2280	...	1049	4 4 7	1231	0 0 4	0 0 1¼
Kendal	13,500	44,500	Intermittent filtration.	16	3,200	192	...	2000	120	5,200	312	...	100	6 5 0	212	0 0 3¾	0 0 1¼
N.B.—Land purchased.																	
SEWAGE PUMPED UP TO LAND AND THE LAND LEASED FOR A LIMITED PERIOD ONLY.																	
Bedford	17,000	65,000	Irrigation.	180	...	...	917	4500 (estimated.)	270	4500	1187	...	1100	6 2 3	87	0 0 1¼	0 0 0¾
Warwick	11,000	44,500	Irrigation.	135	...	...	471	3000 (estimated.)	180	3000	651	471	...	...	180	0 0 4	0 0 1
N.B.—Land yet to purchase.																	

In considering this Table critically it must be borne in mind that when land is purchased by a local authority, and is paid for in thirty years, it becomes a valuable property to the future inhabitants.

The instances tabulated embody three classes for comparison. At Tunbridge Wells and Wolverhampton considerable areas of land have been purchased, and at Kendal a small one; while at Bedford and Warwick the principal portion of the land used for sewage is leased, and will have to be purchased or again leased when the present terms expire. In four instances the sewage is delivered by gravitation and in two by pumping, but in all cases the cost of delivery is excluded from the calculations, and the "charge upon ratepayers" therefore fairly represents the money results of its disposal.

To compare the charges upon ratepayers set forth in this Table with those incurred by dealing with liquid sewage by chemical precipitation—leaving out of consideration the cost of scavenging and the *quality of the effluents* in each case—I may point out, taking Leeds as an illustration of the A B C process, and Bradford as that of the lime process, that in the former case nearly 5d. in the pound, and in the latter about 3d. in the pound, is the charge upon the ratepayers.

The deductions to be gained from a comparison of the charges upon the ratepayers are, first, that it is better at present where land is resorted to, to let the land with the sewage to any substantial tenant even without any advance upon the annual amount the *land* itself costs the authority, as at Wrexham, rather than that a Local Board should turn farmer and occupy the land itself, as at Tunbridge Wells; second, that under advantageous circumstances the charge upon the ratepayers for disposing of sewage after it has been delivered to land will vary from ¼d. to 1½d. in the pound; and, third, that under disadvantageous circumstances the charge for land disposal may reach 8d. in the pound.

The drawbacks which in the present state of our knowledge operate against sewage farming are (1) that the outflow of sewage is constant and must be disposed of without nuisance under any circumstances, (2) that the produce of sewage farming must be of a special character, and at present is confined to succulent fast-growing grasses and market-garden vegetables, (3) that to keep the land as clean as is necessary the employment of a very large amount of labour, and the outlay of a correspondingly large sum of money is necessary, (4) that the home market for vegetables is circumscribed and is often limited to those residing in the town or village from which the sewage

flows, and (5) that if the produce is transported to distant markets it is so much depreciated in value by the journey that the prices realised fail to yield, on an average of sales, an adequate return. These drawbacks apply, invariably, where the quantity of sewage is great, and where it has been desired to turn it to the best account by a distribution over a wide area of land, all experience distinctly proving that the larger the area of land utilised by way of irrigation the greater the loss. (See the description of the Merthyr Tydfil works, Section CI.) Yet, troublesome as these drawbacks are they are as nothing compared to those attending manure-making works if established in inland towns.

The effect, however, has been that up to this time sewage farming and sewage gardening have been found to be profitable only in one or two cases; the practical farmer and the market-gardener being both disinclined in the face of such prejudicial influences to take upon themselves the obligation of disposing of any quantity of diluted liquid that may be discharged from a town. Speaking generally, they each appreciate the fertilising elements which sewage contains as well as the advantage of a plentiful supply of water if applied under favourable conditions. They decline, however, to deal with sewage that they must dispose of at all times, and under all circumstances, in wet weather and in dry weather, in winter and in summer, at night as well as in the day, on Sundays as well as on week days, and when the land is in crop as well as when it is in fallow, simply because they cannot be masters of their own proceedings. (See Section CII.)

Having farmed somewhat largely myself and holding at this moment a small sewage farm, I thoroughly appreciate these objections. Such experience as we have already had unmistakably proves that neither sewage farming aiming at the growth of cereal crops in rotation with pulse roots and artificial grasses, or superior market gardening, which some would call *refined kitchen gardening*, in which lettuces, spinach, onions, and other crops of small growth alternate with coarser vegetables, will pay; but that sewage can be successfully and profitably applied to crops of the cabbage tribe —to mangolds, and other succulent roots—and to Italian rye-grass in areas limited to local demand. We have found, too, that we may occasionally take advantage of land previously sewaged to grow cereals and pulse.*

* See "Half a Dozen English Sewage Farms," by Mr. Chalmers Morton, *Journal of the Royal Agricultural Society of England*, Second Series, vol. xii., part ii.

[The report of the Committee appointed by Mr. Sclater-Booth, the President of the Local Government Board, has been just issued (December, 1876). Without attempting to show in what way sanitary authorities can profitably utilise land purchased or leased for the cleansing of sewage, which it was hoped would have been done, the Committee have been content to reiterate the fact so generally conceded (see Section XC.), that "town sewage can be best and most cheaply disposed of and purified by the process of land irrigation for agricultural purposes where local conditions are favourable to its application," admitting at the same time that "the value of sewage is greatly reduced to the farmer by the fact that it must be disposed of day by day throughout the entire year." The Committee, after giving numerous details, tabulate the results of their inquiries in the following form.

COMPARISON of the Loss of disposing of Town Sewage in proportion to the Annual Rateable Value of the Town.

By Irrigation, plus Scavenging.

Name of Town.	Annual Rateable Value.	Annual Cost in the Pound.
	£	s. d.
1. Banbury	34,104	0 1
2. Bedford	65,000	0 1
3. Blackburn	235,127	0 11¼
4. Cheltenham	217,849	0 0¾
5. Chorley, Lancashire	54,407	0 7
6. Doncaster	68,721	0 3½
7. Harrogate	50,000	0 5¼
8. Leamington	113,400	0 6½
9. Merthyr Tydfil	135,000	0 7½
10. Rugby	45,000	0 1½
11. Tunbridge Wells	142,914	0 10
12. Warwick	43,339	0 6½
13. Wolverhampton	210,000	0 3¾
14. West Derby	163,000	0 5¼
15. Wrexham	32,000	Nil.

By Chemicals, plus Scavenging.

16. Birmingham...	1,229,844	0 10
17. Coventry, by a company ...	101,438	To the corporation nil for disposing of the sewage; but at 5¼d. in the pound for scavenging.
18. Bolton-le-Moors	811,563	0 8½
19. Leeds...	945,141	0 9¼
20. Bradford	745,671	0 6

By the Pail System at Rochdale. The Crude Sewage flows into the River.

21. Halifax	262,581	The crude sewage flows into the river ...	0	4
22. Rochdale	222,000	... ...	0	8¾

By Land Filtration at Kendal..

23. Kendal	44, 600	... ...	0	4

It will be observed by investigating the foregoing Table and comparing its figures with the details upon which it is based (and which the Committee supply), that the conditions of no two towns are alike, and that certain outlay is included in some cases which is excluded in others, so as to produce confusion rather than anything else. Towns where the sewage is pumped are mixed up with those where the sewage is discharged by gravitation, and the "charges upon the ratepayers" are placed in the same column, although the cost of delivery in one case is great and in the other only nominal; while the works of one corporation (Doncaster), having the advantage of utilising their own land which they have let at a *rent, including sewage*, of 3*l.* an acre, are brought into comparison with those of other authorities which have had to pay as much as 12*l.* to 14*l.* an acre to liquidate the cost of the land purchased (Tunbridge Wells and Kendal). Again, taking Banbury and comparing it with Kendal, it will be seen that although 23,400*l.* has been expended in land in the first case, which at 6 per cent. interest to repay the cost would involve an annual charge of 1400*l.* on the ratepayers, *only* 622*l. a year is represented to be the rent of the land utilised*, while in the last case, where a plot of land comprising 66 acres was purchased for 16,371*l.*—of which 50 acres in extent, costing upwards of 13,000*l.* of this money, *have never for a single day been used for sewage*—the whole amount of annual instalment to pay off the 16,371*l.* is charged against the sewage disposal on sixteen acres only! The mode of disposal at Banbury is wide irrigation, involving a loss of 3d. in the pound on the ratepayers, instead of 1d. as represented. The treatment at Kendal is intermittent downward filtration through five acres combined with wide irrigation over eleven acres, and the result has been a charge upon the ratepayers of 1½d. in the pound *instead of* 4*d. as represented in this report!*

As the engineer who advised the Kendal corporation, I

forbear to make any observation on the manner in which this case has been represented by the Committee. I must refer my readers to page 32 of the report, and my own description of the facts in Section CI.

XCIII.—The Solid Matters contained in Sewage. To effect the perfect cleansing of liquid sewage it is absolutely necessary to provide for the treatment of the solid portions in some way or other.

The quantity of the solid portions present in sewage varies considerably, and is increased in proportion as trade refuse is admitted into the sewers. They exist in three gradations of weight and size.

In the *first* are included the bulky substances to which I have before referred, and which would interfere with the valves of pumps if raised, or would be offensive and obstructive to plant growth if distributed on the surface of land. They consist of almost every imaginable thing from a dead cat to a wine cork, and they are generally arrested and extracted by screening. Not being of any large aggregate amount, they are readily removed when screened out of the sewage.

In the solids of the *second* gradation are included the smaller but heavy substances which, after passing through a screen, quickly sink by their weight to the bottom of any tank or receptacle while the sewage is in motion. They include the detritus from roads and other heavy mineral refuse. The road detritus or sand being valuable in itself may be separated from the lighter substances by mechanical deposition in tanks, and this is done effectually in many places.

The suspended substances of the *third* gradation comprise the organic matter and those minute inorganic substances, including very fine sand, which float onwards and deposit themselves very slowly even when the containing liquid is in a quiescent state. When the sewage is in motion the precipitation of these minute substances can only be readily effected by mixture with certain chemicals. This last description of solid matters is technically termed "sludge," and it was with reference to it that the Committee of the House of Commons appointed to consider the Birmingham Sewerage Bill declared that "no sewage should be put upon any land without having been previously defecated in tanks." This unfortunate declaration of a Parliamentary Committee has made "sludge" a much more important item in the sewage question than it could otherwise have become. Not only is it still declared that sludge forms a material from which dry portable manures may be made, but its existence has been asserted to be an obstacle to the

use of land either for the cleansing or the utilisation of sewage, because—mark the statement—*it clogs the pores of the soil!*

Upon these several points I shall have remarks to make hereafter, when I shall hope to place the matter in a very different light.

In the meantime it is desirable that it should be clearly understood that after these solid materials have been extracted as far as they can be, *by artificial processes*, the liquid itself will still contain a great proportion of the polluting matters, and will still have to be cleansed by some supplementary process before it can be legally discharged into any *inland* river or watercourse.

If we read the published statements of the Phosphate Sewage Company, we shall find that that company actually professes to leave the water, after treatment, containing "all its nitrogenous and valuable properties, plus any excess of phosphoric acid which has been added by the process, and therefore *more highly useful* for the irrigation of cereal and other crops." Two other processes—one known as Dr. Anderson's sulphate of alumina process, and the other as Hille's process—do much the same, and these treatments have been supplemented by subsequent applications to land, in order to justify the admission of their effluents into rivers. (See Section XCV.)

XCIV.—Of Sludge. It is necessary to recur more particularly to the third gradation of the solid matter in sewage known as "sludge," because although of very little real value of itself it is the material constituting the corpus or base of the sundry dry manures made from sewage, and because, as already intimated, its existence, ever since the decision of the Birmingham Committee (see last section), has been spoken of as a difficulty in the way of sewage disposal by land, which it is well should be removed from the public mind.

At Birmingham, where the outflow of sewage is about twelve millions of gallons daily, and lime has been used as a precipitant mixed with the sewage at the rate of 23¼ cwt. per million gallons, the road detritus and sludge, together with the lime, amount on an average to about 360 cubic yards daily. Such is the worthless character of the second material (sludge) that no one will take it away at a gift, and it is therefore dug into land forming part of the Saltley Farm and buried out of sight. About one acre a week is so appropriated.

Believing that the sewage of Birmingham contains more than an average proportion of floating solid material we may fairly assume that in a town containing, say 40,000 persons consuming 25 gallons

of water per head per diem, and therefore yielding daily 1,000,000 gallons of sewage proper, the detritus and sludge together will never exceed 30 cubic yards per diem. Of sludge alone the quantity would seldom exeeed 100 grains per gallon, and it is the existence of this material in combination with more or less road detritus that has been made an objection to the use of land for the cleansing of sewage by representing it as "clogging" its pores. It would ill become me to attribute any unworthy motive to those who have done so much to magnify the importance of "sludge," but it may be fairly assumed that where so much capital has been embarked in the purchase of patents, and in launching sewage manure companies, every effort would be made to uphold them, and to show that the solid portion, if of little intrinsic value to the manure maker, may be mischievous when spread on land, and, therefore, must be got rid of in some way independently of land treatment.

My own conviction is that, if properly distributed, sludge on land generally *does good rather than harm*, and that in fact it is very seldom that it has an objectionable effect. (See Section XCVI.) Harm sometimes occurs in wide surface irrigation when the quantity of solid matter discharged from the sewers is very large, such as is the case occasionally when storms wash out the sewers after accumulation of solid matters during drought, and when it is allowed to settle in clots in hollows on the surface to kill growing vegetation, and, possibly, to give off effluvia. Injury to vegetation is more likely to occur under such circumstances when solid trade refuse is admitted into sewers. In the latter case it may be desirable not to depend wholly upon land for the complete disposal of the solid matters, but to have recourse to some means of precipitation which shall concentrate the solid matters and allow of their separate treatment. (See Section XCV.)

At the Lodge Farm, Barking,—at Doncaster,—at Warwick,—at Leamington,—and at many other places in this country, sludge has not been found to be any difficulty at all when applied to land, and the same may certainly be said with regard to the Paris Sewage Farm at Gennevilliers, where the sludge is designedly collected in the furrows by which the liquid is distributed to the growing crops. Already I am glad to say, too, an instance may be quoted in which an urban sanitary authority in the Home Counties has filled up the tanks that had been used for the precipitation of sludge, and has decided upon straining from the liquid applied to the land the coarser matters only, trusting to the soil to appropriate and purify the remainder.

[The report of Messrs. Rawlinson and Read contains the following valuable report of Dr. Voelcker, F.R.S. It exposes with singular force the almost worthless character of sludge when separated from sewage liquid. In order to ascertain the value of the fertilising properties of sewage and excreta, and also of the manures manufactured therefrom and of their commercial value to the farmer, the Committee collected samples at Bolton, Bradford, Leeds, Coventry, Rochdale, and Halifax, and caused them to be analysed by Dr. A. Voelcker, and the following is his report thereon.

"*On the Fertilising and Commercial Value of Sewage and Night-soil Manures.*—The fertilising and commercial value of sewage-sludge and of portable manures prepared from sewage, night-soil manures, and of common farm-yard manure, chiefly depends upon the proportions of phosphate of lime, potash, and nitrogen which these fertilisers contain.

"These fertilising constituents of manures can be bought at the present time in the form of concentrated artificial manures, such as guano, bone dust, sulphate of ammonia, &c., at the following rates:

Phosphate of lime at	1d. per lb.
Potash at	2d. ,,
Nitrogen calculated as ammonia at	8d. ,,

I need hardly say that in such concentrated forms phosphate of lime, potash, and ammonia have a much greater value than they possess in the shape of manures, the bulk of which mainly consists of materials without value, and occurring in abundance in almost every kind of soil.

"I would, however, direct attention to the fact that according to my own experience and that of others, sewage manures, night-soil manures, and ordinary farm-yard manure contain but little ready-formed ammonia, and that by far the largest proportion of the nitrogen in these manures occurs in them in the shape of nitrogenous organic matters, in which form nitrogen is less efficacious, and in consequence less valuable, than in the form of ready-formed ammonia or salts of ammonia.

"In estimating the theoretical value of manures the nitrogen is generally assumed to be present in sewage and similar bulky manures in the form of ammonia, or at all events to have the same value as the nitrogen in the salts of ammonia. This in my opinion is a mistake, and the nitrogenous constituents of sewage manures are valued at too high a rate if their nitrogen is calculated into ammonia, and 8d. allowed for each pound of the calculated amount of ammonia. In order to avoid the charge of having put too low an estimate upon the fertilising constituents of sewage-manures I have allowed in the estimate 8d. per pound for the calculated amount of ammonia which the nitrogenous matters in a ton of manure are capable of gradually producing under the most favourable circumstances on their final decomposition.

The following tabular statement shows at a glance the theoretical or calculated money value of the different sewage manures which were submitted to me for analysis:

" Theoretical or estimated Money Value of one Ton of the treated Sewage Sludge.

	£	s.	d.
(1.) Bolton sludge—from the M. and C. sewage process*	0	9	8½
(2.) The same dried, leaving 15 per cent. of moisture in the sludge	1	1	1
(3.) Solids drained from sewage before the liming process at Bradford	0	11	0½
(4.) The same with 15 per cent. of moisture ...	0	19	3
(5.) Bradford Corporation Sewage Outfall Works, sludge from drying pits, no artificial heat being used	0	4	8
(6.) The same with 15 per cent. of moisture ...	1	0	0½
(7.) Deposit from the sewage of Leeds treated by the A B C process	0	8	4½
(8.) The same with 15 per cent. of moisture ...	0	16	8½
(9.) Manure produced by the General Sewage Manure Company at Coventry	0	16	9½
(10.) Rochdale manure	0	15	11½
(11.) Manure manufactured by the Goux Company at Halifax	0	17	7

" According to the most reliable statements the separation of the suspended matters of sewage by precipitation and filtration, and the production of one ton of dried sewage deposits, apart from the costs of the precipitation agents which are used, entails an expense of about 30s. for each ton of portable dried sewage manure. It is evident, therefore, that the cost of manufacture considerably exceeds the theoretical or calculated money value of every one of the sewage deposit manures, the composition of which is given in the results of analysis in Appendices No. 1, 2, and 3. The estimated money value of sewage and night-soil manures, as has been stated already, does not fairly represent their real commercial value. The bulk of all the samples submitted to me for analysis consists of matters which occur in abundance in almost all soils, and which at any rate have no commercial value, or rather have a negative value, inasmuch as carriage has to be paid for them, and the application of bulky manures necessarily is more expensive than that of concentrated manures, such as guano or bone dust. It is therefore manifestly practically wrong to estimate the money value of such bulky and poor manures by the same standard of prices at which the commercial value of guano, bone dust, sulphate of ammonia, and similar concentrated artificial manures are estimated. A more rational and correct estimate of the true value of sewage and night-soil manures is obtained by comparing them with ordinary farm-yard manure, and the price which is paid for the latter.

" Good farm-yard manure, I find, contains on an average in the ton 6½ lb. of soluble phosphate of lime, 8½ lb. of insoluble phosphate of lime, 13 lb. of potash, and nitrogen equal to 17½ lb. of ammonia.

" By allowing for soluble phosphate of lime 2d. per lb., the same price for potash, 1d. per lb. for insoluble phosphate of lime, and 8d. per lb. for ammonia, the calculated money value of a ton of farm-yard manure amounts to 15s. 7½d., as will be seen from the following figures:

* " M. and C. are the initials of the patentees. The ingredients used are lime, carbon, house ashes, soda, and per-chloride of iron."

	s.	d.
6½ lb. of soluble phosphate of lime, worth, at 2d. per lb.	1	1
8½ ,, insoluble ,, ,, 1d. ,,	0	8½
13 ,, potash ... ... 2d. ,,	2	2
Nitrogen, equal to 17½ lb. of ammonia, calculating ammonia at 8d. per lb.	11	8
Total calculated money value of a ton of farm-yard manure	15	7½

" It thus appears that if we estimate the money value of good farm-yard manure, according to the same rules at which the principal fertilising constituents in the dung can be bought in concentrated manures, one ton of farm-yard manure would be worth in round numbers 15s. However, good dung can be bought in many places at 5s. per ton, or one-third its estimated money value, and practically the highest price which a farmer can afford to pay for good dung, if he has to cart it even a few miles, would not exceed 7s. 6d. per ton, one half its estimated money value. The difference between the estimated money value of farm-yard manure (calculated at the market rate of the constituents when sold as concentrated artificial manures) and the actual market price may be fairly taken to represent the difference in practical value caused by the greater expense of the carriage and application of farm-yard manure, and the less vigorous action of organic nitrogenous compounds as compared with ammonia salts.

" In estimating the commercial value of sewage and night-soil manure, the calculated value of which does not exceed 1*l.* 1s. per ton, precisely the same circumstances have to be taken into account which affect so largely the market value of ordinary farm-yard manure. Accordingly the price which the farmer can afford to pay for the sewage and night-soil manures, analysed by me, or their real money value, will be only from one-third to one-half that of the calculated estimates given on the basis of their analyses.

" The following Table shows the market price or real money value of the various sewage and night-soil manures, samples of which were submitted to me for analysis.

" Practical or Market Value of one Ton of the treated Sludge.

	s.	d.		s.	d.
1. Bolton sludge from the M. and C. sewage process	3	3	to	4	10
2. The same sludge, 15 per cent. of moisture...	7	0	,,	10	6
3. Solids drained from sewage before the liming process at Bradford	3	8	,,	5	6
4. The same with 15 per cent. of moisture ...	6	5	,,	9	6
5. Bradford Corporation Sewage Outfall Works, sludge from drying pits without artificial heat	1	6	,,	2	4
6. The same dried with 15 per cent. of moisture	6	8	,,	10	0
7. Deposit from the sewage of Leeds treated by the A B C process	2	9	,,	4	2
8. The same sludge with 15 per cent. of moisture	5	6	,,	8	4
9. Manure produced by the General Sewage Manure Company at Coventry	5	6	,,	8	4
10. Rochdale manure	5	4	,,	8	0
11. Manure manufactured by the Goux Company at Halifax	5	10	,,	8	9

"In my judgment this tabular statement fairly represents the money value of eleven different samples sent to me for analysis at the place where the manures were produced.

"Some of the products are worth a good deal less than an equal weight of common dung, which fully explains the circumstance that most sewage manures find no ready sale even at a low price, and that in many works such manures accumulate to an inconvenient extent.

"Indeed, comparatively few farmers are so situated that they can afford the expense of carting semi-dried sewage sludge, containing from 60 to 70 per cent. of moisture, from the works to their fields. The refusal to accept such sludge as a gift in not a few instances rather shows sound discrimination than ignorance on the part of the farmers.

(Signed) "AUGUSTUS VOELCKER."]

XCV.—THE CLARIFICATION OF LIQUID SEWAGE BY MECHANICAL SUBSIDENCE OR CHEMICAL PRECIPITATION IN TANKS;—SCOTT'S PROCESS;—AND LIERNUR'S SYSTEM OF TREATMENT. I have stated (see Section LXXX.) that the sewage of towns on the seaboard and of towns on tidal rivers, the waters of which are not used for domestic purposes, may be treated differently from that of towns situated upon inland rivers, the waters of which are used for drinking as well as for other purposes; and I have suggested that in certain instances any one of the tried chemical processes, supplemented or not by land filtration, may be adopted to effect the necessary clarification of the sewage before it is discharged. I have admitted, too, that in very exceptional instances of towns on inland rivers it may be necessary to separate a portion of the suspended matters from the liquid sewage before applying it to land. In such cases tank arrangements must be resorted to, whether the desired deposition is effected simply by mechanical subsidence or by means of chemicals added to the sewage.

Mechanical Subsidence.—The mechanical subsidence of the suspended matters of sewage is generally effected in tanks by the aid of straining divisions of one kind or another. The wider and longer the tank, and the finer the divisions of the screens, the greater the quantity of material separated and deposited. But all tank arrangements are objectionable, whether they be adopted by themselves, or as preliminaries to the cleansing of sewage through land. The object to aim at, therefore, is to limit their use as much as practicable,—and where land is resorted to the minimum tank arrangement may suffice. All that is then required is the straining of the coarse particles, the intercepting of the heavy road detritus, and the extraction of floating trade refuse where it exists in more than the ordinary quantity.

Chemical Precipitation.—There are sundry precipitating processes commanding more or less approval which may be adopted in

aid of natural subsidence. These not only effect clarification, but augment the quantity of deposit—the value of which is in a greater or less degree increased by the character of the chemicals employed in the operation—which when dried becomes a portable manure, and if sold will go some way towards the cost of the chemicals, if it does no more. I will describe the chemical processes which have received the most attention.

(1.) *The A B C, or Native Guano, Process.*—The A B C process is a patented method of treating sewage possessed by the Native Guano Company, who, with a genuine belief in the value of their patent, are pressing it upon the attention of sanitary authorities. The name of this process was derived from the initial letters of the chemicals used—viz., (A) alum, (B) blood, and (C) clay and charcoal. The use of alum, however, has now been abandoned on the ground of expense, and a substitute for it has been found in a crude sulphate of alumina, manufactured, it is stated, at one-fourth the cost. The blood used is mixed with clay when quite fresh, and the mixture is said to act as a fine filter. The clay used acts as a detergent, and is intended to carry down by its weight the alumina precipitate, and to absorb the organic matter in the sewage as well as a proportion of the ammonia. The charcoal acts as a deodorant and decoloriser to absorb and decompose the sewage gases, and to convert them into new compounds. The following extract from a paper prepared by Mr. Rawson, the managing director of the Native Guano Company,* will explain the action which takes place on the mixture of these ingredients with sewage.

"When sulphate of alumina is brought into contact with sewage—a slightly alkaline liquid charged with nitrogenous organic matter—the alumina is separated in flocks, and by virtue of its remarkable affinity for dissolved organic matter, each particle seizes hold of and drags down with it a corresponding particle of nitrogenous impurity. But the precipitated hydrate of alumina is light in character, and although it would ultimately settle, leaving a clear liquid above it, the slightest agitation causes it to float up, and thus renders it difficult on the large scale to drain off the mud. The difficulty, however, is overcome by the introduction of the clay. This substance has a curious physical property; when finely ground up with water it forms a creamy emulsion which takes many days to settle, but on meeting with sulphate of alumina it, like albumen,

* Sewage Conference at the Society of Arts, May, 1876.

coagulates and settles down, in heavy granular flakes. Now, in the process under consideration, the triple precipitation occurs at one time, and the three reagents becoming closely locked together, the heavy character of the clay gives density to the mass, and causes it to settle rapidly and remain in a compact form at the bottom of the tank. Any foul gases that may remain in solution in the water thus cleansed are attacked and rendered innocuous by the charcoal. To the mud is added a small proportion of sulphuric acid, in order to prevent the loss of any free ammonia that may be present, and then it is dried in heated revolving iron cylinders, whence it issues in the form of an inodorous, inoffensive powder."

The process has been tried with unequal results at different places. Among the earliest efforts of the company were those made at Leicester and Leamington, and the following Table taken from the Second Report of the Rivers Pollution Commissioners, shows the extent of purification effected by their treatment of the sewage of the latter town.

—	In Parts per 100,000.				
	Total Solid Matters left on Evaporation.	Organic Carbon.	Organic Nitrogen.	Total Combined Nitrogen.	Suspended Organic Matters.
Raw Sewage	83·5	4·355	2·890	7·807	56·28
,, after treatment by A B C process...	99·2	3·379	1·652	6·392	5·15

The "*Native Guano*" produced by the process was valued by the Rivers Pollution Commissioners at 1*l.* 12s. per ton, and by Dr. Voelcker at the following figures (*Journal of the Royal Agricultural Society*, vol. vi. s.s. part ii.):

	£	s.	d.	
No. 1 sample was worth . .	0	18	6	per ton.
2 ,, ,, . .	1	13	6	,,
3 ,, ,, . .	0	14	0	,,
4 ,, ,, . .	0	18	6	,,
5 ,, ,, . .	0	14	6	,,

the latter basing his valuation on a comparison of the manure with phosphate of lime, at 10*l.* a ton, and ammonia at 60*l.* a ton.

Subsequently the Native Guano Company experimentalised for three months upon some of the London sewage as it was discharged

at Crossness, and Sir J. W. Bazalgette reported to the Metropolitan Board of Works on the 11th January, 1873, as follows:

"Between the 27th August and the 30th November, 1872, 11,672,737 gallons of sewage were experimented upon, being about $\frac{1}{343}$rd part of the average flow of sewage discharged at Crossness, and $\frac{1}{856}$th part of the sewage of London; and about $\frac{3}{7}$ths the quantity proposed to be treated by the company, who intended to have erected two tanks, each capable of containing 125,000 gallons, by the agency of which they stated they would be enabled daily to effect the conversion into solid sewage matter, the deposit from 500,000 gallons of liquid.

"The quantity of A B C mixture used in the shape of alum, clay, charcoal, lime, and blood, amounted to 166 tons, 14 cwt., 1 qr., 13 lbs.; and the sewage treated, assuming it to produce 100 grains to the imperial gallon, 74 tons, 8 cwt., 3 qrs., 16 lbs., making a total of 241 tons, 3 cwt., 1 qr., 1 lb., giving in the shape of dried residue, called native guano, 133 tons, 7 cwt., 2 qrs., 11 lbs. Besides this, the subsiding tanks contained, on the 30th of November last, 41·70 tons more of wet mud deposit than they did at the commencement of the trial; this would produce a dried residue of 8·34 tons.

"The total expenditure amounts to 895*l.* 3s. 3d., and may be divided thus:

	£	s.	d.
Charcoal (refuse animal)	63	14	9
,, (wood)	3	12	6
Alum (crude)	175	14	7
Clay alum	28	18	7½
Clay (common)	18	17	0
Blood	2	13	0
Coals	230	11	3½
Lime	0	6	4½
Wages—			
Manufacturing £220 12 2½			
Mechanical supervision 38 0 10			
Chemical 33 10 4			
Sale account, bagging and loading 8 15 3			
Office, wages of boy 7 16 1½			
	308	14	9
Engine stores	14	7	4½
Manufacturing stores	47	13	0
	895	3	3

"This gives the cost of manufacture, taking the dried and wet residue as perfect native guano (141·7199 tons) at 6*l.* 6s. 4d. per ton, exclusive of rent, interest on capital, depreciation of plant, and other incidental items.

"About 80 tons of the deposit were sent across the river to Messrs. Sillars, who are actively concerned in the management of the A B C Company, to mix with fish manure. Two or three tons of it have been put upon a small quantity of land rented by the company at Crossness; about 10 tons remain in a wet state banked up upon the ground, about 40 tons, in a dried state, are in the company's sheds, and a few tons have been sent away in small quantities as samples, but, with the exception of a few shillings, the company's books show no returns in the shape of sales of manure."

Mr. Keates, the consulting chemist of the Metropolitan Board of Works, on the same occasion, reported that his analyses showed that the mean composition of the effluent water during the three months' experiment was as follows, expressed in grains per gallon:

Total Solids in Solution.	Mineral Matter.	Organic Matter.	Organic Nitrogen.	Ammonia.	Total Nitrogen.
98·70	88·10	10·60	0·188	1·750	1·938

In the middle of the months of September, October, and November, —*i.e.*, on the 16th day of each month—the constituents of the effluent water as ascertained by Mr. Keates' analyses were as follows:

—	Analyses expressed in Grains per Gallon.					
	Total Solids in Solution.	Mineral Matters.	Organic Matter.	Organic Nitrogen as Ammonia.	Ammonia.	Total Nitrogen as Ammonia.
Sept. 16, 1872 ...	149·2	133·5	15·7	0·133	2·100	2·233
Oct. 16, 1872 ...	99·0	88·9	10·1	0·208	2·016	2·224
Nov. 16, 1872 ,,	72·1	62·3	9·8	0·202	1·396	1·598

The results of Mr. Keates' examination of the working of the A B C process at Crossness are thus expressed by him.

"Taking into consideration the results of the Crossness experiment, chemically considered, I come to the following conclusions:

"Firstly. That the effluent water was, on the whole, very good. The A B C treatment so far clarified and defecated the sewage that, looking solely to the physical condition and chemical composition of the water produced at Crossness, I am of opinion that such water was in a fit state to be admitted into any ordinary river with-

out producing a dangerous degree of pollution. I must here again direct attention, however, to the extremely dilute state of the sewage during the experiment. The effect of this was to render the results somewhat inconclusive, as it is of course impossible to say, at least from this experiment, how far the A B C treatment would defecate sewage of a stronger character.

"Secondly. That during the preparation of the manure, including the storing of the moist cakes of mud from the presses, and the final drying in the drying cylinder, no offensive effluvia were emitted, and that, taking the experience of Crossness as a guide, the A B C process may be carried on up to the completion of the manure for the market without producing any nuisance.

"Thirdly. That the value of the manure, as judged of by its chemical composition, does not exceed twenty shillings per ton."

Perhaps the nearest approach the Native Guano Company have yet made towards success has been that accomplished at Leeds. Of the company's trials at this town Mr. Tatham, the chairman of the Sewage Committee, thus speaks (Society of Arts Meeting, May, 1876):

"An agreement was made with the Native Guano Company, the corporation undertaking to erect works to treat two million gallons daily as an experiment; the company to work the process with a stipulated share of the proceeds. This was done, and the company carried on the work at the experimental tank for a considerable time. The effluent water produced was watched with much interest, and analysed by Dr. Frankland and others. Dr. Frankland's report was, that in this effluent the polluting power was 'only slightly beyond the limits proposed by the Rivers Pollution Commissioners,' and this standard, it is known, was very high. A fish lived and thrived in the effluent above three months, whilst another, similarly treated, and placed in a glass globe, but supplied with the town's water, died about two weeks before, thus proving to the Committee, notwithstanding the Commissioners' report, that the A B C process would suffice for the purifying of the Leeds sewage, and that the effluent could be no nuisance to the inhabitants below Leeds.

"After our experience with the trial tank, the Committee resolved, whilst not binding themselves to the A B C, to construct works sufficient to deal with the entire flow of sewage (now between 12 and 14 millions of gallons daily) by precipitation; such works being adapted for any precipitation process. These works have been constructed at a cost, including 25 acres of land, trial works, workmen's cottages, &c., of about 60,000*l*.

"The Native Guano Company not being able, in the face of all the opposition they encountered (official, professional, and otherwise), to sell their manure, on which their success depended, were compelled to discontinue working the process, and terms were arranged between the company and the corporation, annulling the contract between them. The establishment of the value of the native guano being of vital importance to the company, they published numerous testimonials as to its value, but these failed to create a demand. The Committee, to satisfy themselves as far as they could on this point, made trials on six half-acre plots in various dressings, the result showing an advantage of 9s. 1d. on the produce of hay for two seasons, on the plot, in favour of the native guano at 3*l.* 10s. per ton, the value claimed for it by the company, over Peruvian guano at 15*l.* per ton, while the quality of the hay was the best of any, though calculated all at the same price. To determine the value of the native guano as far as possible by actual experiments, quantities varying from half a ton to five tons were given to agriculturists, farmers, market-gardeners, and others, on condition that reports should be furnished to the Committee of the results obtained in each case. Sixty of such reports have been received up to this time, and of these, 40 are favourable, having been tried on grass, turnips, and other root crops and garden produce, thus: 4 on turnips; 20 on general produce; 6 on grain; and 10 on grass.

"The values given vary from 7s. to 80*s.* per ton; only nine give a money estimate; the average appears to be 37s. per ton. Twenty were unfavourable, tried on grain, grass, turnips, &c., but only in four cases on garden and general produce. The estimated value is from nothing to 27s. 6d. per ton. From these returns it would appear that the native guano is best adapted for garden produce. Many of the farmers remark that the season was unfavourable, being too dry.

"The position in which we stand in Leeds to-day, May 1, 1876, may be thus summarised: There is no difficulty in purifying sewage by precipitation, so as to render it admissible into a running stream, especially one like the River Aire, below Leeds, without causing a nuisance, or being injurious to public health, but this is done at a cost. Whether or not this cost can be covered, or a profit made by the sale of the residuum, remains to be seen. The best prospect we have of such return is from the A B C process. We have at present to choose between this and Hanson's" (another process tried by the Leeds authorities); "if his residuum is of equal value with the native guano, and will sell as readily, his would have the advantage; or, if the Native

Guano Company can reduce the cost of their ingredients and working to that of Hanson's, they will have the preference, unless Hanson's residuum sells as well as that of the native guano; but if both can be reduced to the same cost, and have the same return for residuum, then the preference will be for that producing the best effluent, and if these be alike, the two processes will be of equal merit.

"Although this may be taken as the position with us to-day, we are in hopes that further inventions and discoveries may be made, and that the vexed question of the profitable treatment of towns' sewage may in the course of time receive a successful solution."

The cost of the working of the A B C process at Leeds is about 15,000*l.* per annum, including chemicals and labour, but excluding interest on the cost of the works, which would bring the sum to upwards of 18,000*l.** The matter precipitated is estimated at about 20,000 tons per annum, for which there appears to be no sale. This is not promising;—nevertheless there is no doubt that, in the treatment of sewage of towns on the seaboard and on tidal rivers, and indeed of those inland towns *where land is not to be obtained* in the reduced quantity required for intermittent filtration—the instances are, however, very few indeed—the A B C process is one which it may be well to adopt.

At Aylesbury an agreement has only just been entered into be-

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* As the case of Leeds may be quoted as an example of a town where land cannot be resorted to and where chemical treatment must therefore be adopted, it would hardly be right to leave the matter without calling the attention of engineers to the following facts:

1. That the corporation of Leeds have spent between 50,000*l.* and 60,000*l.* in tanks and works required for the chemical treatment of the sewage.

2. That the outflow of sewage from Leeds reaches on an average in dry weather 12½ millions of gallons daily.

3. That the daily cost of chemicals and labour in the treatment adopted is 40*l.*, which is increased to 50*l.* by the interest to repay the cost of the tanks and works.

4. That 60,000*l.* expended in tanks, which are perishable, would have been sufficient to purchase 300 acres of land, which are imperishable, at 200*l.* an acre, and this would have been repaid in 30 years at 10*l.* a day,

That 300 acres would have more than equalled one acre for every 1000 of the population.

That the 12½ million gallons of sewage might be raised on to land 100 feet high for 15*l.* a day.

That the interest on the cost of additional engine power, buildings, &c., together with the interest on the purchase of 300 acres of additional land (if required) would not exceed 15*l.* a day.

Thus the corporation of Leeds might have possessed 600 acres of land if obtainable within a height of 100 feet and within a distance of two miles from the present outfall, and have raised the sewage to it for 40*l.* a day, resulting in a saving of one-fifth the present annual charge on the ratepayers of Leeds, while they would be possessed of an imperishable instead of a perishable property.

The very great attention given to the matter by Mr. Alderman Tatham, is a perfect guarantee that there has been every intention of acting for the best. These remarks upon the case are therefore addressed to the engineering student and not to the ratepayers of Leeds.

tween the Native Guano Company and the sanitary authorities of that town, whereby the company will indemnify the sanitary authority against all risks of Chancery proceedings on receiving a subsidy of 200*l.* a year, together with the use of the tanks and works incident thereto, which cost 2,882*l.* 3s. 6d.* If we add to the subsidy of 200*l.* the annual charge required for the repayment of the cost of these tanks and works—which we will take to amount with attendant expenses to 3,000*l.*—the annual cost of the process to the town of Aylesbury will be about 380*l.*, or about 3½d. in the pound on the rateable value. (See Table in Section XCII.)

But however satisfactory this result may be to the ratepayers of Aylesbury, and however well it may answer the purpose of the Native Guano Company to have that town as a show place, the process can never take the position of the best "practicable" treatment available for a town on an *inland river supplying drinking water to a large population.* In this instance the effluent finds its way into the Thame and by the Thame into the Thames, from which a great portion of the population of the metropolis is supplied with drinking water. The fact that the sanitary authority of Aylesbury has been permitted to adopt this process in such a situation, where land might have been acquired, is a striking illustration of the doubts and indecision still prevailing on a question which ought no longer to be subject to either the one or the other.

(2.) *The Phosphate of Alumina Process.*—This process, which is now being carried into operation by the Phosphate Sewage Company, was patented by Messrs. Forbes and Price. It is thus described by the company:†

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* The precise terms of the agreement supplied me, very kindly, by Mr. Crookes, the chairman of the company, are as follows:

"1. *Subsidy.*—200*l.* per annum and all local rates and taxes that the town would not have had to pay if working themselves. Agreement for seven or fourteen years, and the Native Guano Company deposit 1000*l.* as security for due fulfilment of their agreement, the interest being theirs.

"2. *As to the Use of Tanks and Engine, Buildings and Machinery, &c.*—The town supply these, with the exception of what is specially required for the A B C process, the works having been originally designed by Mr. Hawksley for the lime process. The machinery supplied by the company remains their property. The works and machinery are fully adapted for a town of double the population.

"3. *Disposal of Solid Product.*—The company expect to produce from 600 to 800 tons of dry native guano annually, at a cost not exceeding 35s. to 40s. per ton, and have no doubt of being able to dispose of the whole of the produce at 3*l.* 10s. per ton.

"4. *Guarantee as to Effluent.*—The company guarantee the town from all future difficulty as to the purity of their effluent.

"5. *Standard of Purity.*—Will be within the requirements of the Rivers Pollution Commissioners. As even at Leeds, with the cheap working there, Dr. Letheby's analyses prove the Leeds effluent to be well within that standard in every particular, the company have no doubt the effluent at Aylesbury will be still superior."

† Society of Arts Meeting, May, 1876.

"The Phosphate Sewage Process is based upon the use of specially prepared phosphates of alumina and lime with sewage. The action of the prepared phosphates upon the sewage may be familiarly described as a curdling or coagulation of the fæcal matter in the sewage, giving it thereby a greater tendency to separate itself from the general bulk of water with which it has been intermixed. The next step is the use of lime, and this draws from the sewage the soluble phosphates which have been added in the process, forming therewith what is known as precipitated phosphate. The formation of this precipitated phosphate not only has the effect of recovering from the sewage water the soluble phosphate it contained, but it also carries down with it the curdled or coagulated fæcal matter. The sewage having been thus prepared, a separation of the solid matter is readily accomplished by means of 'precipitating tanks,' constructed so as not to interfere with that quiet condition of the water which is necessary for the deposit of a light and flocculent precipitate.

"By these successive steps the deodorisation and defecation of the sewage are accomplished, so that, whilst a flow of sewage enters at one end of the works, a stream of clear, bright effluent passes away at the other, leaving in the precipitating tanks a deposit of the solid matter which has been separated from the sewage. This solid matter is discharged into shallow beds, where it is allowed to dry, and it is either moulded into bricks and dried in the air, or simply turned over and the drying completed without further trouble, which is undoubtedly the cheapest course of procedure."

This statement fairly represents the operations of the Phosphate Sewage Company, and the work done at Hertford proves that if the aim of the company were simply to produce such an effluent as would be satisfactory in the cases of seaboard towns and towns on short tidal rivers, their process would certainly accomplish that object. The effluent has been reported by Dr. Manning to be "well within the standard of the Thames Conservators"—that standard which has been applied to the sewage of towns on the Thames which are *below* the intakes of the water companies, and where the river water is not used for potable purposes. This standard, however, does not appear to have been recognised by the Thames Conservators as applicable to towns on the upper part of the Thames, the water of which is used for drinking,—and seeing that Hertford is situated on the Lee *above* the intakes of the water companies now supplying water to the eastern part of London, it is incomprehensible why the Conser-

vators of the Lee are content to leave matters as they are.* Little objection, however, can be taken to the work of the Phosphate Sewage Company at Hertford, so long as certain tributaries of the Lee receive the effluent sewage from towns only a few miles above after it has been subjected only to the lime process of precipitation, which was tried, condemned, and abandoned at Hertford itself.

(3.) *The Sulphate of Alumina Process.*—This process was invented by Dr. Anderson of Coventry, and will be best explained in his own words.

"The agent I used as a defecator is sulphate of alumina together with common lime. I use the sulphate, prepared in a rough way on a large scale, by mixing common clay with sulphuric acid in the proportions by weight of two of clay to one of acid. After the clay and acid are well mixed (this can be readily done by steam-worked rollers), I place the mass in a warm place, such as an oven or brick furnace, and leave it exposed to a gentle heat until the acid has combined with the alumina of clay, which combination will have taken place by the time the mass has become perfectly dry and of a greyish hue. In order to use this defecator I allow the sewage to flow into a large tank and add the defecator in the proportion of one pound of the preparation to every one hundred gallons of sewage, or about four tons to the million gallons. Probably when working on a larger scale such as a million gallons, a smaller proportionate quantity of the defecator can be used, without in any way spoiling the result, as I have found it easier to obtain a good defecating action on a large

* The following extract is taken from the report of the discussion at the Sewage Conference held at the Society of Arts, May 9th and 10th, 1876. See Journal of the Society.

"Mr. Cook (Ware) asked what system was adopted with the effluent after it left Hertford Sewage Works before it entered the Lee? He wanted to know if there was not a system of stops, and whether steps were not taken to remove a good deal of the scum from the water.

"Mr. Grindle said the effluent, after leaving the works, did not undergo any treatment whatever, but there were skim-boards put down to take off that low confervoid growth spoken of in Dr. Letheby's report, and to prevent it flowing into the Lee. Every morning a man went down with a net, and wherever he found this flocculent matter he skimmed it off and put it in a receptacle on the bank.

"The Chairman asked the distance from the point where the sewage left the works to that where it entered the Lee?

"Mr. Grindle said about 1,400 yards.

"Mr. Cook said you could see the effects of decomposition in the Lee below the inlet of the Hertford sewage. The water was not fit for drinking purposes. There were hundreds of tons of deposit taken out of the ditch.

"General Scott asked if the confervoid growth spoken of was of the nature of sewage fungus?

"Mr. Grindle said it was called sewage fungus by some persons; but Dr. Letheby called it confervoid growth, and he adopted the name on his authority."

This is an agreeable state of things for the contemplation of the London water consumer.

scale than when acting on a small quantity, but have had no opportunity yet of trying my plan on any such quantity as a million gallons. After agitation all the sulphate of alumina contained in the prepared clay is dissolved out, and if the sewage is alkaline, as sewage generally is, a small proportion of alumina is precipitated and slightly defecates the sewage. In order more fully to develop the action of my agent, I then add common lime well mixed with water, in the proportion of one pound of lime to every four pounds of the sulphate of alumina, and agitate the whole bulk of liquid so as to distribute the action of the defecator evenly. On the addition of the lime a chemical combination takes place between the lime and the sulphuric acid of the sulphate of alumina, and the alumina is set free as a flocculent precipitate. This settles to the bottom, and in the act of precipitation adheres to and carries down with it the impurities contained in the sewage, leaving a clear, bright, supernatant liquid, which requires no further treatment or filtration after settling."

Dr. Anderson's patent has passed into the hands of a company called the General Sewage and Manure Company, of which Mr. Mellis is the engineer. The company have works at Coventry and Nuneaton, and Mr. Mellis describes the arrangements adopted at the former place in the following terms:*

"The sewage is subjected to four processes, viz.—1. Strained; 2. Chemically treated and precipitated; 3. Effluent water filtered; 4. Precipitate or sludge dried and disposed of.

"The straining is effected by means of mechanical strainers, known as 'Latham's Solid Sewage Extractors.' The solids thus removed form a rich manure, which, at the present time, is used in the orchard adjacent to the buildings of the works. The strained sewage thus free from all its grosser contents, and, therefore, in a better condition for chemical treatment, next passes through a block of buildings, where it receives continuously an addition of a solution of sulphate of alumina, manufactured and prepared in a cheap way at the works, which contain all the necessary appliances for this purpose. The sewage next receives a small addition of milk of lime, and, after the addition of each chemical, the whole mixture is thoroughly agitated. The mixture then passes on to the precipitating tanks, of which there are four, three being in use at the same time, while a fourth is being cleaned out daily. Precipitation takes place in these tanks, while the effluent water flows in a thin sheet

* Society of Arts Meeting, May, 1876.

from the surface, first, over weirs extending quite across the tanks, and secondly, over weirs which extend half way across each tank. An arrangement of sluices and valves exists at the end of each tank for drawing off the water from the precipitate or sludge when a tank has to be emptied.

"The effluent water is conveyed from the tanks by a culvert and open carriers to filtering beds, of which there are three, each three acres in extent; the water then percolates through a depth of five feet of earth, and is afterwards discharged through three 15-inch mains into the river. This water is clear, bright, and of a good standard of purity, and, according to analysis by Dr. Voelcker, contains in each imperial gallon, 45·22 grains of solid matter, and only ·630 of a grain of free (saline) ammonia, and ·042 of a grain of organic (albuminoid) ammonia.

"The filter beds are used intermittently, and are cropped with osiers and rye-grass. The latter is pleasing to the eye, and assists in keeping the beds in good condition.

"The sludge or deposit found on the bottoms of the precipitating tanks, after the water is drained off, contains about 85 per cent. of moisture, and amounts during 24 hours to about 25 tons. It is one of the chief characteristics of this process, that scarcely any solid matter is permitted to enter with the chemicals. The sludge, therefore, is almost entirely derived from the sewage, and is thus reduced to a minimum bulk. This fact renders it much less difficult, and less costly to dispose of than the large quantities of sludge which result from the lime and other precipitation processes, which require large quantities of chemicals with their solid portions to enter the sewage.

"The sludge is swept from the bottoms of the precipitating tanks into underground chambers, placed below their level, in which simple arrangements exist for drawing off supernatant water; it is then elevated by ordinary chain and bucket elevators, and passed through Milburn's continuous sludge-filters, which, without the application of heat, remove about 20 per cent. of moisture, and reduce its bulk to about 10 tons per day. The sludge in this somewhat stiff condition, containing about 65 per cent. of moisture, is next subjected to a comparatively small amount of heat in Milburn's sludge-drying machines, which remove a further 5 per cent. of moisture. It is a remarkable fact that this sludge thus treated, and having been once subjected to heat, continues afterwards, when placed in heaps, to part with its moisture until it retains only 9 or 10 per cent.

"By these means the daily precipitate at Coventry is converted into

about 4½ tons of a dry manure. This manure, according to analysis by Dr. Voelcker, contains, in addition to other fertilising agents, 1·67 per cent. of ammonia, and 3·75 per cent. of phosphate of lime, and may be valued according to chemical values at 35s. or 40s. per ton.

"The whole of the sludge is not, however, reduced to a dry condition in the manner just described. Some portion of it is, after passing the non-heating continuous filter, fortified and dried by the addition of chemicals and fertilising agents, thus producing a good manure which is brought up to an average value of 5*l.* or 6*l.* per ton, and competes well with the best artificial manures produced in this country. A considerable quantity of the sludge is also, in the stiff and semi-dry state in which it comes from the non-heating continuous filter, bought and carted away by the landowners in the neighbourhood."

The Sulphate of Alumina Process, however, is not a self-supporting process, the expense attending the separation of the sludge and its conversion into a portable manure being much greater than the actual value of the manure itself.

The Paris sewage was subjected to treatment by sulphate of alumina, and the process after trial was abandoned.

(4.) *Whitthread's Process.*—This process appears to have come to a standstill, but as it has been spoken well of by some able authorities, I think it well to describe it in the words of the inventor.*

"Dicalcic phosphate dissolved in an aqueous solution of monocalcic phosphate is added to the sewage as it flows from the sewers; when the whole is well mixed, milk of lime is added in sufficient quantity to precipitate all the phosphates, while an excess of lime is carefully guarded against. The quantity of phosphates to be added depends on the quantity of nitrogenous organic matter in solution in the sewage.

"Dicalcic phosphate has the power, when used as above described, to carry down with it organic matter, and especially nitrogenous organic matter; thus it removes those bodies most prone to decomposition, which are, at the same time, the most valuable manurial ingredients in the sewage. The resulting deposit consists of a nitrogenous calcic phosphate. The working of the process is simple in the extreme, and requires no special knowledge; it can be regulated by rule of thumb. The tanks and mixing apparatus used are similar to those employed in other precipitation processes, only as the precipitation is very rapid, tank room may be economised.

* Society of Arts, May, 1876.

"The precipitate is of a most valuable nature. The agent used, in itself a valuable manure, is always entirely recovered in the mud; the phosphoric acid existing in the sewage is likewise secured, and as the dicalcic phosphate efficaciously precipitates the putrescible organic matters, the quantity of nitrogen existing in the precipitate is very large. The manure contains no water of chemical combination; it is thrown down in a flocculent state, being perfectly inodorous, and can be easily dried. Numerous experiments have been made in this direction and the drying difficulty has been solved in various ways."

The process was tested by the Sewage Committee of the British Association by an experiment made on 100 gallons of sewage taken from the Romford sewer before it joined the tanks on Breton's Farm, one pound of the dicalcic and mono-calcic phosphate being stirred up in a little water, and added after the addition of a little milk of lime. The precipitation was very rapid, and the Committee stated that the supernatant water remained very nearly clear and quite inoffensive.

The Committee give the following Table in their report showing the result of the analyses of the raw sewage, the supernatant water, and the precipitate:

Description of Samples.	Results given in Parts per 100,000.											Remarks (by Dr. Russell.)
	Solid Matter.				Chlorine.	Nitrogen.						
	In Solution.		In Suspension.			In Solution.				In Suspension.	Total in Solution and Suspension.	
	Dried at 100° C.	After Ignition.	Dried at 120° C.	After Ignition.		As Ammonia.	Organic.	As Nitrates and Nitrites.	Total.			
Sewage sample from 100 gallons as it entered the tanks	71·20	41·40	24·14	9·68	11·57	2·28	0·90	...	3·18	1·93	5·11	
Supernatant liquid filtered ...	83·8	56·2	...	...	11·21	2·50	0·02	none.	2·52	...	...	$P_2O_5 = 5·53$.

Examination of the precipitate after drying it at 100° C.

Results in 100 parts.

Ammonia	3·03
Phosphoric acid (P_2O_5)	8·18
Lime (CaO)	23·51
Phosphate of alumina and iron	5·94
Loss on ignition	32·86.
Residuum, insoluble in hydrochloric acid	14·54

The Committee add: "We have said that the suspended matters were in very small amount in the supernatant water; this is evidently merely a question of time allowed for settling. It will be seen that the amount of ammonia in solution is somewhat greater in the effluent water than in the sewage, doubtless from the decomposition of some of the soluble organic matter in solution; but the most remarkable thing is that the organic matter in solution was almost entirely removed in this experiment, so that while the sewage contained 0·90 part of organic nitrogen in solution in 100,000 parts, the supernatant water only contained 0·02 part. It must, however, be distinctly understood that this is only a preliminary experiment, from which general conclusions must not be too hastily drawn. The supernatant water contained a considerable quantity of phosphoric acid, viz., 5·53 parts in 100,000.

"The analysis of the precipitate shows it to contain a large proportion of phosphate of lime; and its value is much enhanced by the three per cent. of ammonia which it also contains.

"The presence of phosphoric acid in the supernatant water would be of considerable advantage if this were afterwards used for irrigation, but, unless means are devised for separating it, would constitute a serious loss if the water were thrown away.

"On the whole, then, this preliminary experiment shows that the process in question well deserves further and careful investigation."

Mr. Whitthread, in a letter, reminds me that his "process for treating sewage was to remove the greater portion of the organic impurities from the sewage by adding dicalcic phosphate, and then to completely oxidise any organic matter which might remain by filtration." My own examination of this process enables me to speak favourably of it where clarification only is the object aimed at. It was tried at Luton, but was not however approved.

(5.) *Messrs. Weare and Co.'s Process.*—By this process the clarification of the sewage is effected, first, by simple filtration through coarse ashes and charcoal, performed in a tank called the fæcal tank, next, by filtration through a series of wooden screens containing certain thicknesses of rough charcoal, and, lastly, by special filtration through "deodorisers" formed of rough and fine charcoal. This method has been tried at the Union workhouse at Stoke-upon-Trent (I do not know of any other trial), and was the subject of examination by the Sewage Committee of the British Association, in 1871. The result of their investigation is thus given:

"The process of purification of the sewage is protected by a patent. It consists, in the first instance, of simple filtration through coarse

ashes and charcoal, performed in a large tank called the fæcal tank, which is divided into two compartments, so that one may be at work while the other is being cleared. These compartments are again subdivided into two chambers, one large and one small. The raw sewage is brought to a small receiver and from it turned, by means of sluices, into either compartment. The samples of sewage taken by the Committee's inspector were obtained from this receiver; the flow was ascertained to be about 5,000 gallons in the twenty-four hours, being much below the capacity of the filters, which were constructed for 20,000 gallons per day. From the large chambers of the fæcal tank the sewage is passed through wooden screens, containing 2 feet of charcoal, into the small chambers, which contain about 5 feet 6 inches of rough charcoal, through which the sewage passes to a smaller tank or well, thus completing the first stage of filtration. The suspended matters are partly arrested by the wooden and charcoal screens between the large and small chambers, and a further deposit takes place in the small chamber, which is cleared once in six months; but at the time of the Committee's inspection it had not been cleared for nine months, owing to the constant visits of persons anxious to inspect the process. Samples of the sewage at this stage of the process were duly taken. From the tank or well before described, the sewage (after again passing through a perforated screen containing 6 inches of rough charcoal) is conveyed by a 12-inch pipe to the 'deodorisers,' which are, in this case, at some distance from the fæcal tank.

"The 'deodorisers' are three in number—the first and largest having a surface area of nearly 200 square feet, and containing 5 feet 6 inches depth of rough charcoal; the second, with an area of about 70 square feet, contains 2 feet 6 inches of charcoal of smaller size; the last is a small box containing 4 feet of fine charcoal, which is in this instance supplemented by layers of flannel and filter-cloth. It was stated, however, that cloth is not a necessary addition if the tanks are specially constructed, in which case the last deodoriser is arranged for upward filtration. This completes the process, the effluent water being discharged into a small well, from which the samples were taken for analysis.

"The charcoal used at the time of the Committee's inspection was wood-charcoal; but it was stated that it was proposed to use peat-charcoal. The practice is to remove the 'spent' charcoal from the last deodoriser to the second one, from the second to the first, and from the first deodoriser to the fæcal tank. Samples were taken of charcoal from each deodoriser after various periods of service, and analyses of them and of unused charcoal are appended.

"The flow of effluent water for the period of twenty-four hours, during which continuous gaugings were taken, amounted to about 2000 gallons only, as against 5000 gallons of sewage received into the fæcal tank during the same period. The deposit removed from the tanks, with the refuse of the establishment, is utilised upon the farm belonging to the Union, which is cultivated entirely by the inmates."

The Committee give the following results of the analyses of the different samples of sewage, effluent water, and charcoal which were taken during the month of September, 1871. The samples of sewage and effluent water were taken every two hours during the day, in the proportion of one-thousandth of the flow per minute.

Description of Samples.	Results given in Parts per 100,000.											Remarks (by Dr. Russell).
	Solid Matter.				Chlorine.	Nitrogen.						
	In Solution.		In Suspension.			In Solution.				In Suspension.	Total in Solution and Suspension.	
	Dried at 100° C.	After Ignition.	Dried at 120° C.	After Ignition.		As Ammonia.	Organic.	As Nitrates and Nitrites.	Total.			
Sewage from receiver before treatment	163·80	87·50	171·40	59·45	28·12	24·01	4·94	...	28·95	9·5	38·45	
Sewage after passing through "fæcal tank" filters	85·70	56·50	8·05	1·50	14.91	9·76	0·63	...	10·39	1·27	11·66	
Effluent water after passing through deodorising tanks ...	68·90	54·40	...	...	14·20	2·15	0·63	None.	2·78	...	2·78	Had strong smell of Sewage.

ANALYSES of Samples of Charcoal.

	In 100 Parts.	
	Water, &c., dried at 100° C.	Ammonia.
Charcoal before use	24·20	0·0014
Charcoal after five weeks' use in No. 3 deodorising tank, to be applied to No. 2.....	50·42	0·0018
Charcoal after two months' use in No. 2 deodorising tank, to be applied to No. 1	55·61	0·045
Charcoal after five months' use in No. 1, to be applied to fæcal tank.....	54·12	0·082

With regard to the analyses, the Committee observe, "in the first place, that the sewage treated was excessively strong, containing no less than 38·45 parts of nitrogen (in solution and suspension) in 100,000 parts of sewage; this is accounted for by the very scanty water supply, from which it results that the amount of sewage is only 6⅔ gallons per head in the twenty-four hours.

"The general result of the process is that the suspended matters are removed and the ammonia and organic nitrogen much reduced in quantity; no oxidation takes place, as no nitrates were found in the effluent water, which was to all intents and purposes a dilute sewage and 'had a strong smell of sewage.'

"It is remarkable that the chlorine is reduced to just about half its original amount; and it is still more remarkable that this should take place almost entirely in the first or fæcal tank: this reduction would seem to imply that a very considerable dilution must in some way take place; and notwithstanding this we find that there were only 2000 gallons of effluent water to 5000 gallons of sewage in the twenty-four hours, indicating an unexplained escape of ⅗ths of the total amount, even supposing that there was no dilution.

"The amount of water absorbed by the charcoal, although, as indicated by the analyses, considerable, does not of course in any appreciable degree account for such a loss."

(6.) *Hille's Process.*—Captain L. Flower, the sanitary engineer of the Lee Conservancy Board, attaches great importance to this process. He says of it, "that it will be difficult to find a more efficient, harmless, and economical manner of treating sewage."

By this process, the inventor says, "sewage may be successfully defecated and deodorised by the aid of lime, tar, salts of magnesium or other chemicals, and the products arising from the calcination of lime. The effluent water is afterwards filtered, either by preference through artificial filters or through land, or it may be used for irrigation purposes: the results thus obtained have been found to reach the standard of purity required by the Thames Conservancy," and also, we are told, that recommended by the Rivers Pollution Commission. The inventor further says that "The disinfecting compound — which does not contain any poisonous or injurious constituents—is applied to ordinary town sewage in the proportion of about 1 in 2,000. It may be added to the sewage at any convenient point before the sewage reaches the deposit tanks, or, as it flows into the works. The thorough amalgamation of the chemical compound and the sewage is effected through agitation by mechanical means, after which the whole is allowed to

accumulate in the deposit tanks, where nearly the whole of the suspended matters are deposited, together with a considerable quantity of the various matters held in solution. Any deposit tank may be used in connection with my system. In tanks constructed after my design—after the sewage has been chemically treated, the supernatant liquid is drawn off by means of a floating outlet through a regulating valve: this outlet is formed of strong galvanised wire, the interior of the cage being filled with mixed charcoal. From the deposit tanks the purified sewage passes on, if not used for irrigation purposes, to the artificial filtering beds, which are so designed that the filtering materials have time for thorough and complete aëration. Where possible, carbonic acid gas is forced into the filtered effluent water: this gas is a waste product of the lime, which may be burned on the premises. The outlet chamber is provided with a second floating outlet with a governor regulating valve. The works and everything connected therewith are in duplicate and may be used alternately, or, if required, simultaneously. The sewage residue is removed daily from the tanks, so as to have daily fresh sewage to treat, and to avoid accumulation of the sludge. The sludge is removed into the drying sheds, simply air-dried, and in that state constitutes a good manure.

"The total cost of working this process, exclusive of the value of the manure produced, varies from 3d. to about 1s. per head of the population per annum, according to local circumstances. The value of the precipitated sewage residue will vary in different districts, but it is calculated to be worth, on the average, 26s. per ton in its raw state. It forms a good manure which, when mixed with the charcoal from the filtering beds, has the value as per analyses, from 3*l*. to 4*l*. per ton."

There are several other processes which have for their object the conversion of the solid parts of sewage into dry manures by the agency of chemicals, amongst which may be mentioned the methods known as Bird's system and Holden's process, in which sulphate of iron, lime, and coal-dust are used. Of these I have heard but little for some time, and must refer those interested to the inventors themselves for details.

There is Hanson's process also, which has been on trial for a short time at Leeds, in competition with the A B C process, and of which Mr. Tatham gave the following account at the conference on the Health and Sewage of Towns in May last.

"Hanson's process as first used was not successful in discharging

the colour when the sewage was impregnated with dye-water, but by subsequent experiments, and using a fresh ingredient, which he calls hœmatite, he finds he can purify the sewage at a cost, for about 22 tons of ingredients per day, of 14s. 6d. per hour for the total daily flow of 12 to 14 million gallons, being about 29s. per million gallons, which amounts to 17*l.* 8s. per day, or 6,200*l.* a year, the A B C being about 24 tons, 18s. 3¾d. per hour, or 22*l.* 1s. per day, equal to 8,048*l.* a year. Against the advantage of Hanson's reduced cost, there is no off-set for value of residuum—no price for it having yet been established—the inventor claims that it is of equal or greater value than the native guano."

The precipitating material used by Mr. Hanson, if I rightly understand it, is slaked lime and black ash refuse—or the soda and tank waste from the alkali works—mixed with sulphuric acid. For ordinary sewage the quantity of precipitating material employed is about one ton of slaked lime, used in the form of a creamy paste, and half a ton of black ash refuse for each million gallons of sewage, together costing about 18s. Where tan liquor is mixed with the sewage, he uses a further quantity of black ash refuse mixture, which increases the cost about 11s., making the outlay about 29s. per million gallons. Mr. Hanson's explanation of the action of the materials he employs is that the black ash refuse throws down the carbonate of lime as well as the nitrogenous and other impurities left in the liquid after the lime has been added.

No description of chemical processes would be perfect without some reference to the lime method of precipitation, which was tried many years back at Leicester and Tottenham and discontinued, though it has since been adopted, and has still, I believe, a lingering existence at Birmingham and elsewhere. It has also been in use at Hitchin for many years, but is now being discontinued in favour of intermitttent downward filtration. The *modus operandi* is very simple, but as Mr. Burke says of it, "the treatment entirely fails to get rid of the organic nitrogenous matter of the sewage, and, consequently, to render the liquid sewage admissible into a river."* The Sewage of Towns Commission gave the following Table in their second Report (1861), showing the results of an examination of the process by Professor Way. The figures given represent the constituents in grains per gallon.

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* "A Handbook on Sewage Utilisation," by W. R. Burke, Barrister-at-law.

——	Before Treatment.	After Treatment.	Precipitate.
Organic matter:			
(*a*) Insoluble suspended	39·10	—	—
(*b*) Soluble	19·40	19·35	35·41
Lime	10·13	9·28	14·80
Magnesia	1·42	0·94	0·22
Soda	4·01	2.26	1·02
Potash	3·66	3·80	
Common salt	26·40	24·49	
Sulphuric acid	5·34	5·99	1·11
Phosphoric acid	2·63	0·45	2·06
Carbonic acid	9·01	5·19	8·92
Silica, sand, oxide of iron, &c.	6·20	0·23	5·96
	127·30	71·98	69·50
Ammonia	7·48 in solution only.	7·50 in solution only.	2·80

Upon these figures Professor Way remarks:

"1st. That no organic matter is precipitated except that which was present in the sewage in the insoluble form and which would equally have been separated by mechanical filtration.

"2nd. That the ammonia in the precipitate is entirely due to the same insoluble organic matter, and that none of the ammonia of the liquid is saved by this process.

"3rd. That the potash being soluble is in the same way entirely carried away by the liquid.

"4th. That five-sixths of the phosphoric acid are precipitated.

"With the exception of the latter, therefore, no element of agricultural value is preserved by the lime process."

(7.) *The Burning of the Combustible Parts of Sludge in the Manufacture of Cement and Limes.*—A plan differing from all the foregoing processes has been matured and patented by General Scott. Mr. Redgrave, the secretary of "Scott's Sewage Company," thus shortly describes it. "This process is a modification of the well-known lime process. It has been long known that lime carefully slaked and added to sewage water produces a copious precipitation, consisting mainly of carbonate of lime with small quantities of phosphate and silicate of lime. Clay is also a valuable agent in clarifying sewage water. General Scott adds a sufficient quantity of slaked lime to produce a complete precipitation of the acids present in the sewage, and enough clay to form, with the silica and alumina already

present in the sewer water, about 20 per cent. of the bulk of the calcined sewage sludge. This precipitate when it has completely subsided is removed from the tanks and dried. When thoroughly dry the sludge is introduced into kilns with a small quantity of fuel to commence the combustion. It is calcined by means of its own organic matter, and the clinker after such calcination is withdrawn from the kilns and ground under edge runners and between French-burr stones to a fine powder. One million gallons of average town sewage treated with 1 ton 5 cwt. of slaked lime yield 4 tons of dry sludge, and, when burnt, 2 tons of Portland cement."

(8.) *Liernur's System.*—Few inventions of modern days have exhibited greater ingenuity or presented details more worthy the study of engineers than the Liernur system as carried out at Dordrecht, Amsterdam, and other towns in Holland, at Prague, Brünn, and Olmutz, in Bohemia, and at St. Petersburg, but up to this time no example of its applicability has been established in this country. Such are the social habits of the people, and such the progress already effected in sanitary science, that it would be taking too sanguine a view to suppose that the Liernur system will ever gain any wide application here.

Captain Liernur proposes to deal with each class of impurity in the following manner. The town is divided into districts consisting of from 200 to 1000 houses according to local circumstances, each district centering in an air-tight iron tank about three feet underground. This tank is connected with the closets of the houses by air-tight pipes. In a convenient part of the town is placed a central station with air-tight reservoirs, and engines. This station communicates with each district tank by a separate system of pipes. (See Drawing XVI.) By means of the pipes converging at the central station, the air is exhausted out of any given district tank, and the vacuum power thus exerted draws the excretal refuse from each house-closet pipe connected with that tank. This process is repeated in every district or division of the town, and the collected matter is drawn through the central pipes to the central station, and there converted by evaporation into a concentrated dry powder containing, it is stated, 10 per cent. of ammonia. The heat employed for the conversion of the collected matter into a powder of this character is that contained in the exhaust steam of the engines used *à triple effet* as in sugar reducing.

The following are the principal features claimed in favour of the pneumatic system by Captain Liernur's representative in this country, Mr. Adam Scott.

(1.) *Emptying of Pipes.*—This takes place daily.

(2.) *Piping.*—All 5 inch cast-iron socket pipes—lead and tow joints.

(3.) *Pressure.*—This instead of being outward, as in gas and water pipes, is inward by reason of the vacuum. Thus in case of a loose or dislocated joint, the lead, tow, and earth would be drawn in and the joint made tight.

(4.) *Valves.*—There are no valves in the whole system of pipes, nor any moveable mechanism except the cocks at the junction of street and central pipes with tanks. These cocks are like those used in water mains, and can be lifted up and examined at any time.

(5.) *Closets without Water.*—These are composed of two funnels, syphon and soil pipes, and two ventilating pipes, one for the funnels the other for the soil pipe. (See Drawing XVI.) By the action of an air-sucker (not known in England), there is a constant current from the closet apartment into the closet and out to the roof of the house.

(6.) *Water-Closets.*—Only those of a water-saving character, and even those reluctantly, are admissible, as they dilute the manure and affect the cost of evaporation.

(7.) *Mode of Working.*—Patrols of men, in twos, turn the cocks in connection with the street tanks.

(8.) *Stoppages in Pipes.*—If Captain Liernur's plans are followed these are impossible. People can stop up their closets but not the pipes, anything getting into which is carried without fail to the central station.

(9.) *Equalisation of Resistances in Pipes.*—This is obtained by creating artificially, barometrical columns of matter in the house barrel pipes (see Drawing XVI.).

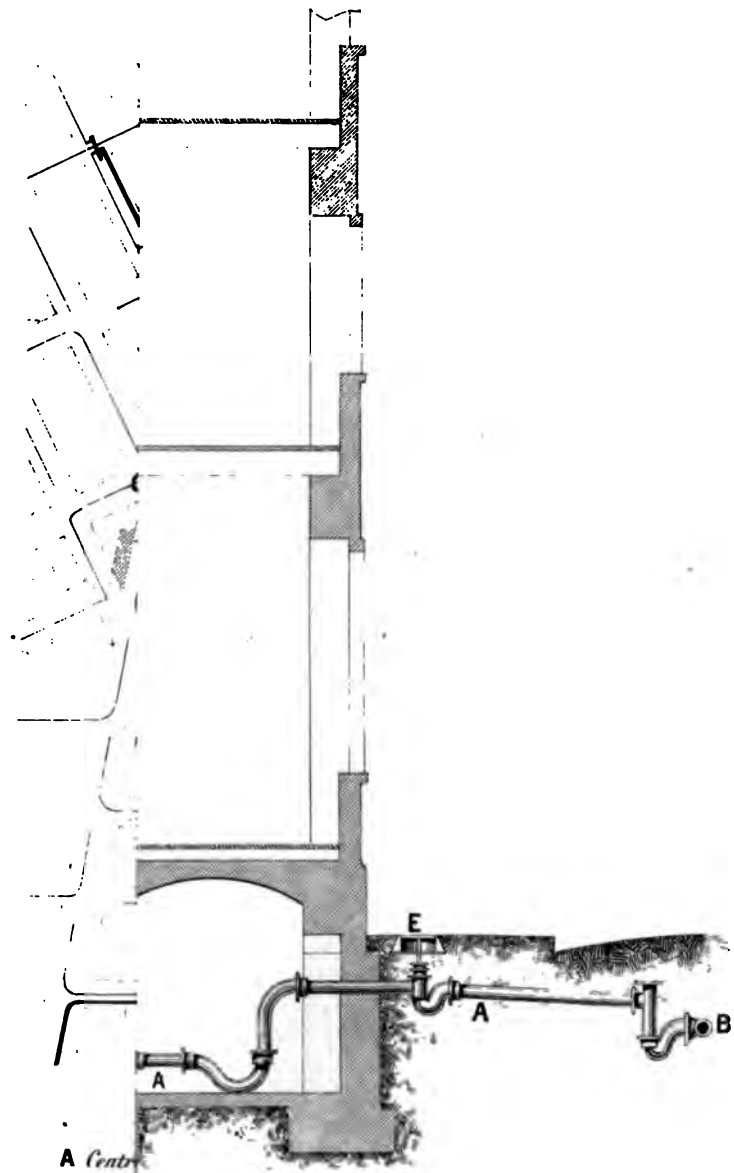
(10.) *Sink Refuse.*—This is received in a kind of trap which retains the suspended matters, the bulk of the liquid passing away through an upward strainer, not into the air-tight pipes, but into the house-sewer leading to the common sewer for separate treatment by coke filters. The deposit is collected daily in the same way that the contents of the closets are collected. By this trap all connection between house and sewer is cut off.

(11.) *Waste Water of Trade.*—This Captain Liernur requires to be purified before it leaves the manufacturer's premises. It then enters the same conduit as the overflow liquid from the sink trap. To insure its purification before discharge, Captain Liernur constructs a bend in the drain pipe from the factory to the sewer in

Sanitary Engineering THE TOWN AND VILLAGE.

Drawing XVI.

TEM



A *Centr*

B *Centr*

C *Distr*

One Dist

INDEX

Pipes to Street Main.

ain.

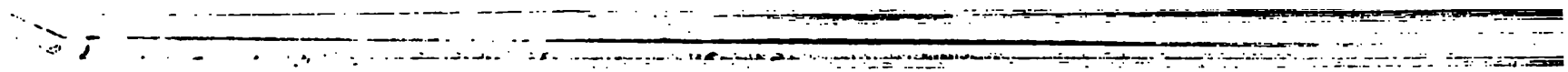
g Pipe to Soil Pipe.

g Pipes to Closets

ve to disconnect the House in case of Repairs or Accidents.

BAILEY DENTON, SON, & NORTH.

22, Whitehall Place, LONDON



which some of the water must always remain. A thin stand-pipe to the pavement from this bend enables the inspector of nuisances by means of a small hand-pump to take a sample for examination at any time.

(12.) *Street Mud and Detritus.*—This is not allowed to enter the sewer. The street gullies are provided with moveable iron buckets into which all the water enters by a funnel, but can only get to the sewer by filtering upwards round the funnel through a loosely woven thick straw mat, all the coarse particles being cast down into the bucket, and removed from time to time by scavengers.

(13.) *Rain Water, Subsoil Water, and House Water.*—These all go into the common sewer which receives the overflow from the sink traps, and the water from trade premises. The contents of this conduit are filtered through gas-coke filtering beds.

(14.) *Common Sewers and Subsoil Drainage.*—Where sewers do not exist, Captain Liernur would construct new ones of vitrified earthenware so as to prevent the sewage getting out or the subsoil water getting in. For the drainage of the subsoil water so as to keep it at a permanently low level, a separate set of agricultural drain-pipes are used, which discharge at intervals into the common sewer.

(15.) *Influence on Health.*—Mr. Scott considers that it has been shown by five years' experience in Holland that the pneumatic system, by removing excrement without any possible pollution of air, soil, or water, has banished typhoid and diphtheria, as well as cholera and any diseases that are conveyed by the discharge from the intestines.

XCVI.—The Advantage of retaining the "Sludge" in the Liquid Sewage when it is applied to Land. Having expressed a very decided opinion that *artificial* treatments of sewage are only admissible when land cannot be obtained, it is desirable to show that "sludge" is not a bar to the application of sewage to land. It is only necessary to remember of what substances "sludge" is composed, to be satisfied that it cannot possibly permanently clog any soil. It consists of vegetable and animal substances which are perishable, mixed with earthy and mineral substances which are not perishable, and exist in very small particles. Of the latter the most minute consist of road sand, the particles of which still float on after the heavier detritus has deposited itself. When these perishable and imperishable substances find their way into the interstices of the soil they must each, from their nature, obviously add to its porosity. The perishable substances leave open spaces as they decay, while the imperishable

substances from their gritty nature necessarily help to improve its filtering powers. So long as the sludge is wet it impedes absorption to a certain extent, but when once dried and the land broken up by the plough or the scarifier, it not only ceases to uphold the liquid, but materially and permanently increases the absorptive powers of the soil.

In intermittent downward filtration, the deposit of the sludge takes place in the furrows which form an essential feature in the system, although by skilful management other forms may be adopted; and we find in practice that the furrows when first used absorb the sewage too quickly, but that as the deposit of sludge accumulates in the bottom it resists infiltration and drives the sewage into the ridges on each side, and so distributes it more equally than if the furrows alone absorbed it. As soon as the deposit of sludge is sufficient to prevent infiltration in any great degree, the sewage is withheld from the areas so affected for a few days. The sludge is thus allowed to dry (partially) in the furrows, and when in a fit condition it is lifted and dug into the ridges,—as can be seen practised every day at Gennevilliers (Paris).

The slimy matter which had appeared so considerable when in a wet state shrinks to a skin of very insignificant thickness when dry, and is readily broken up and mixed with the soil.

These remarks apply to the mechanical action of sludge upon the soil. The floating ingredients of a fertilising character being of the small commercial value that has been represented (Section XCIV.) they cannot be more easily or more economically disposed of than upon land, or more cheaply distributed than by the same vehicle which conveys to the land the more valuable—*i.e.*, the soluble—materials of the liquid sewage. The very trifling value of the suspended ingredients, indeed, renders it all the more desirable that they should be disposed of by the same means and at the same time as the liquid.

The objection raised to the spreading of sewage, containing solid ingredients in suspension, amongst growing plants, because those solid matters will cling to their stalks and leaves, vanishes altogether when furrows are made the channels of distribution, and when no more sewage is distributed on the surface of land than vegetation requires, and the land will absorb. It is only when the pernicious practice of *flooding* land is resorted to that sewage will rise up among the stalks and leaves growing upon it. At Gennevilliers the sewage never touches the vegetation growing in the irrigated ground. It is distributed throughout the entire breadth of the plains by furrows in

the way I have always adopted in intermittent filtration to secure the uniform cleansing of sewage. (See Section CI. and Drawing XVII.)

XCVII. — CIRCUMSTANCES UNDER WHICH THE SPECIAL TREATMENT OR RIDDANCE OF SLUDGE MAY BE NECESSARY. Although I am very sanguine that with increasing experience in using and cleansing sewage, we shall find that straining will suffice to free it of the only materials which would be obstructive and offensive when delivered into furrows or spread over the surface of land, I am at present obliged to admit that circumstances may occur in which it would be advantageous to subject the sewage to chemical treatment in order to precipitate the finer particles after the coarser substances have been removed by the strainer. This obligation will arise but seldom in either intermittent downward filtration or wide surface irrigation, if the distribution is well managed—the exceptional instances being when the quantity of light flocculent matter is greatly in excess of the ordinary amount, or where trade liquids, in which the suspended matter is of a nature deleterious in itself, are discharged into the sewers.

XCVIII.—THE TEMPERATURE OF SEWAGE. It will not require further remark to render manifest that I regard land as the only *certain* medium of freeing sewage of its foul and noxious matters; and, before explaining the manner in which land can be rendered capable of performing this duty, it should be stated, in anticipation of the objection, often raised, that frost acts as a bar to the distribution of sewage on the surface of land in the winter season, that Mr. William Haywood, the engineer to the City of London, having carefully ascertained the temperature of the internal air of sewers, and compared it with that of the external air for a whole year, found the mean winter temperature of the former to be 11·61 deg. higher than the latter, while it was 3·07 deg. higher in autumn, and 0·06 deg. in spring. In summer the sewer air was 3·12 deg. colder than the outer air.

The following Table gives the comparative figures:

Time of Year.	Temperature in External Atmosphere in Shade.			Temperature in Sewer.		
	Highest.	Lowest.	Mean.	Highest.	Lowest.	Mean.
	°	°	°	°	°	°
Summer	72	55	65·04	68	56	61·92
Winter.....	34	30	32·37	52	40	43·98
Spring	61	46	52·46	59	48	52·52
Autumn	68	48	59·90	70	53	62·97
Average of whole year .	...	...	50·24	...	...	55·35

The Sewage Committee of the British Association ascertained at Merthyr that on the coldest day during the time the observations were made, the difference between the temperature of the sewage delivered to the filtration areas, and that of the air was 8 deg., while the temperature of the effluent water discharged from the under-drains was found to be one degree higher than sewage itself. The observations to which I refer were made for eight days in January, and in July, 1872. They were recorded as follows:

Date.	Temperature.				Date.	Temperature.			
	At Noon.		Average during Day.			At Noon.		Average during Day.	
	Air.	Ground.	Sewage.	Effluent Water,		Air.	Ground.	Sewage.	Effluent Water.
1872.	° F.	° F.	° F.	° F.	1872.	° F.	° F.	° F.	° F.
Jan. 9.....	...	...	49	46	July 2.....	70	63	60	56
10.....	50	49	49	46	3.....	70	64	60	55
11...	49	48	50	47	4.....	75	73	60	55
12.....	48	46	48½	45	5.....	69	70	60	56
13... .	49	47	47	45½	6.....	68	70	55	68
14.....	50	49	48	46	7.....	68	64	60	55
15.....	40	38	43	45½	8.....	68	44	60	55
16.....	37	39	45	46	9.....	68	50	60	55

The figures in these two Tables will probably satisfy you that the distribution of sewage on land is not likely to be much impeded by frost, and that when collected in furrows, as is the case in intermittent downward filtration, the sewage will thaw the frozen condition of land with which it may be brought in contact. I point this out because the Rivers Pollution Commissioners in their examination of the effluent water from the Croydon Sewage Farm, on the surface of which the

sewage is spread by *wide irrigation*, found that during frost in winter it was slightly less pure than at other times, from which it would be inferred that the frozen condition of the soil at a time when the assimilative functions of vegetation were dormant was the cause of the inferior character of the effluent. This would in itself suggest that it would be better to have in readiness an area of furrowed filtration ground to receive the sewage during frost whereby the greater depth of sewage would ensure a higher degree of temperature.

XCIX.—Land the Purifier of Liquid Sewage and Liquid Sewage the Fertiliser of Land. I desire, before entering upon the different modes of purifying and utilising sewage by land, to reiterate the fact that it has only been by bringing sewage in contact with natural soil, that purification and utilisation have been satisfactorily united. Whether sewage be applied to a broad area of land by surface irrigation, or to a limited area by intermittent downward filtration, the effects which head this section are invariably the result of the contact in a greater or less degree. To use the words of Dr. Forbes, "the process in either case is to bring into action a mechanico-chemical treatment; the soil acting mechanically as a filter, whilst the oxidising action of the air in the soil and the growth of vegetation on the surface bring powerful chemical agencies into operation, and decompose and assimilate the organic and other compounds in the sewage which may be available as fertilising ingredients."

It is hardly necessary again to remind you that while the several chemical processes I have just described aim at converting the suspended substances of sewage into a portable manure, they admittedly fail in cleansing the liquid, so as to free it perfectly of "its foul or noxious matters." In truth, as already stated, the promoters of some of these processes look to the supplemental act of passing sewage through soil as a means of completing the purification which they have failed to secure by chemical treatment alone. We want nothing more than this to justify the preference for land as the purifier of sewage. It is quite true that we yet want proof that a *profitable* return can be continuously obtained by plant growth from the use of sewage in any shape, but I hope with the evidence already obtained of the power of sewage to stimulate vegetation and produce maximum crops, to show before I have done, that by avoiding the imprudence of acquiring larger areas of land than are wanted we may ultimately realise the real value of liquid sewage. Up to this moment the minds of the agriculturist and the horticulturist have not been brought to bear upon the subject in union with

those of the chemist and the engineer, and until they have been we must be content with the present bewilderment. The general rate-paying public, seduced for the time by scientific theories put forth by Liebig, Boussingault, and other chemists of renown, have been led to believe that the fertility of land may be thoroughly well sustained by the application of the liquid sewage of twenty persons to an acre. But this has not borne the test of experience. With the compulsory cleansing of sewage, under all conditions, we have learnt that theory and practice are not at present reconcilable, and the effect has been that those who would study true economy find it better to adopt as a starting-point the minimum extent of land that will suffice for the purification of the sewage rather than the maximum that may possibly be fertilised by a given quantity of sewage—taking care to increase the area wherever there exists good local markets, or other conditions to ensure the sale of sewage produce at full compensating prices, and never neglecting to lay the foundation for extension as opportunity may arise.

C.—Wide Surface Irrigation. The difficulties which beset the sewage farmer and the sewage gardener, and which have thrown considerable doubt upon the probability of ever deriving a profit from the utilisation of sewage on land, have been already referred to in Section XCII., and again at the close of the last section. It now becomes my duty to describe the different ways of preparing land for cleansing and utilising sewage.

The mode of treatment to be first considered is "*Wide Surface Irrigation*," a term which is used to express the distribution of sewage over as wide a surface of land as can be fertilised by its application without precise regard to the *regular* absorption and infiltration of the sewage, although every drop to be purified by the process must ultimately pass through the soil before it reaches the outfall stream.

To meet and overcome the difficulties of a varying character of soil and a varying inclination of surface by appropriate distribution, is not an easy matter. Land may not only be too retentive or too porous, but its surface may be too steep or too flat, and the mode of distributing sewage on land must therefore be governed by the degree in which these natural conditions exist.

Wide surface irrigation does not, as was a few years ago considered, consist of *flooding* undrained land with liquid sewage when in a state of saturation; but it consists in distributing sewage on the surface of land in such a quantity as will satisfy

the demands of vegetation *without waste* and satisfy the absorbent powers of the soil *without overflow*. One acre to every 100 persons is considered to be a proper provision. Very few years back it was believed to be right to run sewage over land in the same way as water irrigation is practised in the valley of the Po in North Italy, and in the valleys of the Avon and the Test in this country, where the melting snow from the Alps in the one case, and the outbursting springs from the chalk in the other, supply a superabundant flow, and where the warmth and quality of the waters stimulate a prolific growth of herbage in an opportune season. The offensive practice of "flooding" is, I am sorry to say, still continued on some sewage farms. It is even stated to be the right thing to encourage, and where the object is to get rid of an excessive quantity, and so dispose of a troublesome matter, it may be pardonable, but to do so where the land is laid down with Italian rye-grass which will swallow up a large quantity of sewage, or on land which happens to be in a fallow state, in the slap-dash style adopted by some persons, cannot be justified on any rational ground. Such acts of extreme waste, attended as they frequently are with positive nuisance, cannot be called either *farming* or *gardening*.

Very few years back the advantages of aëration of soil were ignored, and underdrainage, without which aëration cannot exist, was regarded rather as an evil than as a benefit, because it caused a waste of valuable liquid. I remember being ridiculed at a discussion at the Society of Arts, some ten years back, for insisting upon the underdrainage of all lands to which sewage might be applied as the chief means of freeing irrigation from the objections raised to it. Irrigation, as true science has since recognised it, is, I repeat, the application of a given quantity of sewage to as many acres of land as will produce a maximum growth of vegetation without supersaturation of soil. The quantity will necessarily vary according to the character and quality of the soil to which the sewage is applied. Natural or artificial drainage is indispensable. An able and experienced irrigator of the present day does not allow a drop of sewage to flow off the surface into the river as was formerly the case under the pretence that it was cleansed, but if the quantity distributed on the surface is not absorbed it is reapplied to lower land, adjusting the application to the demands of the growing crops and to the capability of the land to absorb and cleanse the sewage. It is only in the case of stiff retentive soils that any reapplication of sewage is necessary.

(1.) *Suitable and Unsuitable Soils.* — Speaking generally the

greater its natural fertility the more suitable is all land for irrigation, inasmuch as the stimulation of plant-growth by a covering of liquid can only be maintained under every atmospheric change by a natural productive power in the soil from which it springs. Though poor land will become productive under the process, the best returns from a given outlay are gained from a soil naturally fertile.

Having reference to the mineral constituents of soils—irrespective of the organic matters which may exist in them to increase their natural fertility — the most suitable soil is a loam with a small proportion of gritty gravel to give it a percolative property, which in other words means natural drainage. The soils most unsuitable are very stiff clays, very coarse gravels, and boggy peat lands. When saying this of clay soils I desire to record my conviction that the day is not far distant when a mellow clayey soil—*i.e.*, a loamy clay—will be placed amongst suitable soils; but to attain this character such soils must be properly drained and properly prepared by deep cultivation, and, if necessary, by mixture with burnt clay, ashes, and sand. Upwards of thirty years' practice in land drainage in this country leads me to the conviction that clay soils should be avoided if other and freer soil can be obtained, because in the absence of the essential conditions which I have specified they fail to gain an uniformly percolative character, and it is not often that Local Boards will incur the outlay necessary to prepare them properly. Soils in which clay exists will crack, and the raw sewage applied to the surface will descend by the cracks directly down to the drains, and will pass away to the rivers and streams in a condition almost as foul as when it was applied to the surface. This was the condition of the land at Norwood, which had been drained in an agricultural fashion before the sewage was applied to it, when it was found to be necessary to remove or to stop up the drains. To overcome this is a real difficulty, but where no choice exists and necessity gives birth to invention, the difficulty and objection will cease, and we shall learn that land, to which sewage is applied, is rather the better for having a moderate proportion of clay in it.

The superior properties of aërated (drained) clay consist in its affinity for ammonia, and the extreme comminution to which it is reducible by the action of air and water. Under proper treatment a loamy soil becomes, in fact, not only more productive, and therefore a better purifier, but a better filtering material than either gravel or coarse sand. You must not, however, misunderstand me. I do not recommend clay soils for sewage-cleansing in the present state of knowledge, for our authorities have not yet realised that it is more

economical to thoroughly prepare a small area of land by draining, trenching and mixing, than to use a large area which has only been indifferently treated, and until they do, the engineer must be content to await the growth of experience, and the lessons sanitary authorities will gain from failure. It will be well understood that those who would crowd thousands of tons of sewage on land producing Italian rye-grass to rise up amongst the free-growing foliage, and those who would let sewage, when in excess, run loose on a fallow surface of open porous soil, to go where it will for chance absorption, and call such practices "sewage farming," would declare that clay lands—which stubbornly resist such treatment—are altogether unsuitable.

The effect of irrigation on an undrained clay soil may be seen at Harrogate, Earlswood, and other places. At Harrogate, where the sewage is applied on the catch-water system to lands undrained, or imperfectly drained, the sewage does not penetrate the soil to any appreciable extent, except in the dry days of summer, when the atmosphere does the work of tillage by cracks and pulverisation. It is in winter when the land is thoroughly wet and vegetation inactive, that a considerable portion of the suspended matter is carried over and off the surface into the streams by the irrigating liquid which leaves the land almost as foul as when it was delivered to it. I have traced at Harrogate the coagulated solid matter, which had passed from the tanks on to the land, from one bed or terrace to another, and then on to others, until it ultimately reached the stream (Beck) which supplies waters to riparian owners lower down its course. This condition, I believe, is now undergoing alteration. At Earlswood a similar result attended the distribution of sewage upon lands of which the inclination of the surface was very much less than that which exists at Harrogate. The Sewage Committee of the British Association reported upon this case as follows:

"It will be remembered that the Committee investigated the utilisation of the sewage of Redhill, Surrey, at Earlswood Common, and reported the result at the last meeting of the British Association at Edinburgh. In this report the extent and mode of laying out the land and applying the sewage were described, and analyses were given of samples of the sewage and effluent water taken by the Committee. The results of these analyses showed that the sewage, although very weak, was but very imperfectly purified by the process; and that this was so, was attributed by the Committee chiefly to the absence of underdrainage in the irrigated land, the analyses and various observations as to the temperatures of the samples point-

ing to the conclusion that the land had become saturated, and that the sewage simply flowed over it instead of percolating through it.

"The Committee has again examined this farm, considering it desirable to ascertain and report any change of circumstances connected with it. No sampling of the sewage or effluent water was made on this occasion, as it was found that the farm remained very much in the same condition as when last visited.

"The outfall ditch, which receives the effluent sewage from the lowest beds, has been lowered two feet, so as to admit of subsoil-drainage over the whole farm; but none has been executed, although the idea was at one time entertained.

"The crops on the farm consist principally of rye-grass and oats, with a few mangolds. The rye-grass, of which three crops have been cut this year, is for the most part made into hay, *there not being sufficient demand for it in the green state.* It should be stated that on the occasion of this inspection the effluent water was running apparently clear and free from smell."

These two cases are sufficient in themselves to show that clay lands *in an undrained condition*, though they may carry good crops under the stimulating influence of sewage, and produce a fair effluent in summer, cannot in any way be relied upon in winter. They require all the help the engineer can give them by underdrainage and surface preparation to render them suitable all the year round.

That soils may be much too free in character, as well as too dense, has been shown at the Lodge Farm, Barking, where flooding has been adopted to an extent which though not reaching the quantity of sewage applied at the Heathcote Farm, Leamington, will surprise the student of agricultural economy. At Barking as much as from 10,000 to 15,000 tons of sewage,—and if I remember rightly even much more,—have been applied to an acre of gravelly land. This is remarkable, but its application as a farmer's act will become more striking when it is stated that 4000 tons were applied to an acre of loamy land at the same time, and produced the same quantity of grass. Both applications were greatly in excess of what was necessary to produce the crop, but the excess of the one over the other at once conveys to the mind that in the first case from 6000 to 11,000 tons of sewage were positively thrown away. I would particularly draw attention to this fact, as it confirms, first, the statement that clayey soils possess superior natural capabilities of production, and second, that inasmuch as no grass crop, however thirsty may be its character, can appropriate more than a very minute proportion of the fertilising elements which such copious applications contain, the rest must be irrecoverably lost by being

washed down into the lower depths of the subsoil. This is termed "intensified irrigation!" To bring fully to the mind the amount of waste resulting from such flooding of land, it should be understood that a dressing of liquid sewage half an inch deep containing 50 tons per acre, is far more than sufficient to invigorate and fertilise any growing crop, and that 15,000 tons per acre represent 300 dressings of the same depth, or one dressing nearly every day but Sundays throughout the whole year. Converted into gallons, 15,000 tons become 3,360,000, or a quantity equal to the average outflow of sewage from 360 people for a whole year, and seeing that whenever sewage is applied in large quantities to sloping ground—and all sewage farms are laid out in slopes—it must necessarily run into the lower parts, it may be taken for certain that there are certain parts of every field—the hollows and slacks—that naturally absorb double this quantity per acre. This approaches the quantity cleansed by the process of intermittent downward filtration, which does not profess to make the growth of vegetation a primary object, though when carefully combined with irrigation it furnishes the only certain means of turning sewage to a profitable account. The crop produced at the Lodge Farm from the 15,000 tons of sewage was Italian rye-grass, of which each ton was obtained at an expense of 375 tons of sewage (84,000 gallons), a quantity equal to the ordinary daily discharge of a town of 3000 or 4000 inhabitants. If we put the price of the sewage at one-fourth of its theoretical value, *i.e.*, at a halfpenny a ton, we shall still find that its cost exceeds the selling price of the grass independently of the outlay in rent of land, labour, seeds, &c.

At Lord Warwick's Heathcote Farm, Leamington, a larger quantity of sewage has been applied to Italian rye-grass than even that which I have quoted as the acreage quantity occasionally used at the Lodge Farm. The tabular statement given by Mr. Morton in an essay on "Half a Dozen English Sewage Farms" (*Journal of the Royal Agricultural Society of England*, Second Series, vol. xii. part ii.), shows that 279,010 tons (62,498,240 gallons) have been applied to less than 14 acres of light loamy land. This is equal to very nearly 20,000 tons (4,480,000 gallons) of sewage per acre, or the annual liquid refuse of about 500 persons using 25 gallons of water per head per diem, which if valued at only a halfpenny a ton would amount to 41*l.* per acre independently of rent, labour, seeds, &c. Lord Warwick, however, pays for the sewage of Leamington, which in 1875 amounted to 1,451,930 tons, much less than a halfpenny a ton. He pays in fact not quite the third of a farthing per ton. At this price the cost of the sewage swallowed up by this field alone,

assuming every acre to receive an equal quantity, is upwards of 6*l.* per acre. To supply Lord Warwick with the sewage for which he pays the 450*l.*, the sanitary authorities of Leamington have expended upwards of 16,000*l.* in erecting pumping works, the annual instalment to repay which, together with the current cost of pumping, amounts to about 2000*l.* a year, or about 1s. 10d. per head of the population, so that each acre receives, when so deluged, sewage which costs the town 27*l.* 11s. an acre to pump. In the eyes of the ratepayers nothing could be much more forbidding to sewage farming than these figures, and in the interest of agriculture I protest against the shortsightedness which would hold this instance up as one to copy.

In applying these figures to the question of suitable and unsuitable soils, I should explain that the swallowing up of so much sewage is due rather to an improper mode of application—quite inconsistent with sound sewage farming,—than to the condition of the land itself. Still it is undoubtedly true that the extreme porosity of certain soils renders the economical application of sewage most difficult, for, in order to get the sewage from the higher part of the slope down to the lower part, the former must be in a saturated condition, and this can only be attained by a sacrifice of sewage to some extent. The treatment of the sewage at Eton may be instanced as a case to be studied by the sanitary engineer. There "the troublesome matter is got rid of" in a ready way without any great profession of farming. There is this amount of satisfaction, however, to be gained even from the practices adopted at the Lodge Farm and the Heathcote Farm and at Eton: the soil absorbing these large quantities of wasted sewage, either cleanses it of its foul and noxious matters, or the whole is lost in the subsoil, while the extraordinary quantities swallowed up conclusively prove that it is hardly possible to overdose free soils. This precisely agrees with my experience in intermittent filtration. There is this great difference however between the *ad captandum* practice of crowding sewage upon any surfaces that will absorb it and the process of intermittent filtration, that while in the former case the liquid will run down into the lowest places to form pools of the most objectionable character, such results are impossible with properly executed filtration areas, which are so designed as to absorb evenly all the sewage that is brought to them without any chance of overflow. Let me repeat, the soil most suitable for wide-surface irrigation is a free soil with a small proportion of clay in it—sufficient clay, in fact, to moderate the percolative powers of its other constituents. The fol-

lowing Table will be useful in calculating the area over which a given quantity of sewage may be distributed in required depths.

TABLE showing the Extent of Land, in Acres and Decimal Parts of an Acre, which will be benefited by Sewage Dressings of Different Depths or Quantities.

SEWAGE TO BE DEALT WITH DAILY.		AREA REQUIRED IF THE QUANTITY TO BE APPLIED BE					
		¼ in. Deep, or 12½ Tons per Acre.	½ in. Deep, or 25 Tons per Acre.	¾ in. Deep, or 50 Tons per Acre.	¾in. Deep, or 75 Tons per Acre.	1 in. Deep, or 100 Tons per Acre.*	2 in. Deep, or 200 Tons per Acre.
Gallons.	Cub. Feet.	acres. dec.	acres. dec.	acres. dec.	acres. dec.	acres. dec.	acres. dec.
5,000	802	1·768	·884	.442	·294	·221	·110
6,000	962	2·120	1·060	·530	·353	·265	·132
7,000	1,123	2·472	1·236	·618	·412	·309	·154
8,000	1,283	2·828	1·414	·707	·471	·353	·176
9,000	1,444	3·180	1·590	·795	·530	·397	·198
10,000	1,604	3·536	1·768	·884	·589	·442	·221
20,000	3,209	7·04	3·52	1·76	1·17	·884	·442
30,000	4,813	10·60	5·30	2·65	1·76	1·32	·663
40,000	6,418	14·12	7·06	3·53	2·35	1·76	·884
50,000	8,022	17·68	8·84	4·42	2·94	2·21	1·10
60,000	9,627	21·20	10·60	5·30	3·53	2·65	1·32
70,000	11,231	24·72	12·36	6·18	4·12	3·09	1·54
80,000	12,836	28·28	14·14	7·07	4·71	3·53	1·76
90,000	14,441	31·80	15·90	7·95	5·30	3·97	1·98
100,000	16,045	35·36	17·68	8·84	5·89	4·42	2·21
200,000	32,091	70·4	35·2	17·6	11·7	8·84	4·42
300,000	48,137	106·0	53·0	26·5	17·6	13·2	6·63
400,000	64,182	141·2	70·6	35·3	23·5	17·6	8·84
500,000	80,228	176·8	88·4	44·2	29·4	22·1	11·0
600,000	96,274	212·0	106·0	53·0	35·3	26·5	13·2
700,000	112,319	247·2	123·6	61·8	41·2	30·9	15·4
800,000	128,365	282·8	141·4	70·7	47·1	35·3	17·6
900,000	144,411	318·0	159·0	79·5	53·0	39·7	19·8
1,000,000	160,457	353·6	176·8	88·4	58·9	44·2	22·1
2,000,000	320,914	704·	352·	176·	117·	88·4	44·2
3,000,000	481,370	1060·	530·	265·	176·	132·	66·3
4,000,000	641,827	1412·	706·	353·	235·	176·	88·4
5,000,000	802,284	1768·	884·	442·	294·	221·	110·
6,000,000	962,741	2120·	1060·	530·	353·	265·	132·
7,000,000	1,123,198	2472·	1236·	618·	412·	309·	154·
8,000,000	1,283,656	2828·	1414·	707·	471·	353·	176·
9,000,000	1,444,112	3180·	1590·	795·	530·	397·	198·
10,000,000	1,604,579	3536·	1768·	884·	589·	442·	221·
20,000,000	3,209,140	7072·	3536·	1768·	1178·	884·	442·
30,000,000	4,813,709	10608·	5304·	2652·	1768·	1326·	663·
40,000,000	6,418,279	14144·	7072·	3536·	2357·	1768·	884·
50,000,000	8,022,849	17680·	8840·	4420·	2947·	2210·	1105·

* One inch of water over an acre of land is equivalent to 22,622 gallons, or 101 tons less 2 gallons. One ton of water = 224 gallons; 100 tons = 22,400 gallons.

(2.) *Underdrainage and Surface Preparation.*—The two works of underdrainage and surface preparation which are necessary, the one to prevent wetness and the other to secure an even distribution of the sewage over the surface, must each be regulated by the character of the soil.

Underdrainage.—Where free soils naturally dry are fed with only sufficient sewage to wet and manure them to the extent required to insure the production of the desired crops, no artificial underdrainage may be necessary, though if the mode of distribution involves such flooding as I have spoken of at any time, underdrainage is more or less necessary. In fact, drainage can never do harm, while if the subsoil partakes of a retentive character drainage is indispensable. In soils comparatively free in character but few drains are required, and they should be so placed that if practicable no sewage shall travel directly over them, or otherwise it may pass through the moved soil, with which the drain is covered, down to the pipes, and find its way out of them into the river or stream in an impure condition. Where clay soils, which are better avoided, must be resorted to, the drains to overcome the natural retentiveness of the land will necessarily be frequent, and they should be so laid out as to allow the sewage if possible to be twice applied—that is to say, the underdrains of the land to which the sewage is first applied should discharge their effluent upon a lower surface of land, by which any impurity retained after the first application may be removed by the second. When this arrangement cannot be effected the surface must be deeply and perfectly trenched so as to secure that disintegration which will prevent its cracking and give it an uniform filtering power. If the land is not susceptible of this condition, it should remain undrained, and the sewage after passing over its surface should be conducted to a small area of land of a free character specially prepared for intermittent filtration, or, failing a free soil, to a bed of clay *specially prepared* for the like purpose. Thus, any foul and polluting matter which it held on leaving the clay surface above may be removed by passing through the soil to which it is afterwards applied.

Surface Preparation.—In preparing land for wide irrigation the inclination which it is necessary to give the surface will entirely depend upon the character of the soil and subsoil. The whole area of the sewage farm must necessarily be laid out in slopes, ruled in size and position by the configuration of the surface and the degree of porosity the soil possesses. With very free soils a gradient of 1 in 25, or as much as 1 in 20, may be necessary to gain an overflow which

will cover the surface and prevent excessive absorption, though on very suitable soils a flat slope of 1 in 150 may be a workable gradient. Those farmers who are compelled to dispose of the sewage delivered to them, be it much or little, and have taught themselves to believe that growing crops cannot have too much of it, confessedly aim at supersaturation to effect the distribution of the sewage upon which they put but little or no value, and my friend Mr. Morgan of the Lodge Farm, who will give his rye-grass as much as 10,000 to 15,000 tons of sewage per acre per annum, and whose experience entitles his opinion to great weight, goes so far as to say that the wider the slope, even on a free soil, and the more sewage consumed to get the liquid to flow from the top of the slope to the bottom, the better. At the Lodge Farm the gradients from ridge to furrow vary from the steepest I have mentioned to 1 in 120. Having been closely connected with agriculture the greater part of my life, I know practically how necessary it is with the quality of labour at command to leave as little as possible to the discretion of workmen in farming operations of all kinds. This experience leads me to the conclusion that although horse and plough should always take the place of man and spade where it can possibly be done when bringing land into shape for sewage, the general slopes should be so laid out that it should be impossible for the waterman either to bury the liquid in the way I have spoken of, or to run it into the watercourses, for in nine cases out of ten this abuse of valuable matter will take place if the waterman has his own way.

It is difficult to lay down any precise rule whereby "even" distribution may be effected. In every case trial must be made of the soil under treatment before finally fixing upon the best surface gradients, always remembering that as a good gardener never over-waters his plants, because he knows they thrive better with just a sufficiency to thoroughly wet them, so the irrigator should avoid supersaturation as an evil. Speaking theoretically,—if the liquid to be utilised by vegetation, and the foul matters to be removed by the soil, could be together spread over a perfectly level surface, the most *even* appropriation and absorption by plant and soil would be gained, and if properly regulated the best results would follow. Practically, however, we know that the different degrees of porosity existing in all soils interfere with this arrangement and compel the adoption of suitable inclinations according to their character. It cannot be too well understood that if wide slopes are formed, and the waterman is directed to flood the land with sewage so long as it is absorbed regardless of the quantity applied, the land so treated becomes no-

thing better than a badly made filtering bed, and such treatment destroys the prospect of sewage farming ever becoming either a profitable or a scientific operation.

(3.) *Delivering Conduits, Tanks, Sluice Chambers, and Distributing Carriers.*—Of these various appliances it may be said that whenever their position can be determined, and there is no doubt of their continued utility in such position, they should be regarded as permanent works and constructed in a substantial manner.

Delivering Conduits.—This remark particularly applies to *conduits* intended to deliver the sewage from the outfall sewer to the different parts of the farm at a height to command internal surfaces. If their purpose is simply to convey the sewage from one point to another, and they can pass underground, carefully jointed circular stoneware pipes will form the best conduits. These pipes will themselves bear some pressure when properly jointed, and where connected with iron pipes to cross streams and the deeper depressions of surface, may be used with advantage and economy. I need not say that it will be easy to misplace these pipes. Where the land is cultivated with the plough they should not be less than two feet under the surface. When delivering conduits are intended to part with sewage and feed distributing carriers on their way from one point to another, they must necessarily follow the surface itself. They may then be constructed of concrete shaped to any required form, or of bricks laid in cement, or of shaped stoneware.

Figs. 127 and 128 represent carriers of the last description—manufactured by Doulton and Co.

Tanks.—Before the sewage discharged by the sewers of a district can be applied to land in any way, it is desirable, though it may not be absolutely necessary, to separate the coarser particles of the suspended materials from the liquid. (See Section XCIII.) For this purpose some description of straining is always required. This straining cannot be done without some tank arrangment, in which to fix the screens and strainers, and collect the materials as they are separated from the liquid. The first strainers—if there are more than one set in the tank—consist of wrought or cast-iron gratings, and are found to answer their purpose very well. The spaces between the rods, or the openings in the castings, vary from half to three-quarters of an inch in width. These spaces should be arranged so as to be capable of being easily raked out and freed of all solid matters impeding the passage of the sewage through them, and the solid matters as they accumulate should be removed by manual power, or by a mechanical lift attached to the engine if the sewage be lifted.

Fig. 127.

Fig. 128.

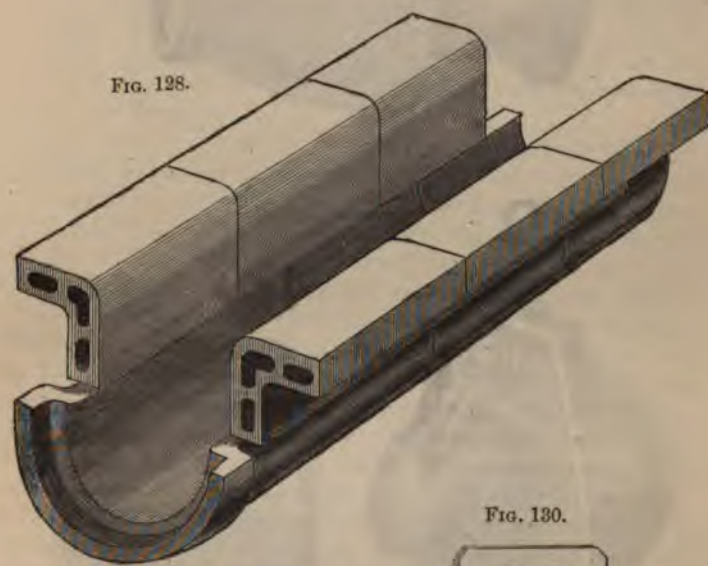


Fig. 130.

Fig. 129.

FIG. 131.

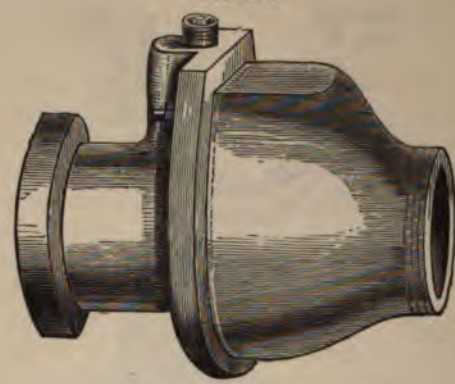


FIG. 132.

FIG. 133.

Fig. 135.

FIG. 134.

In those cases where pumping is resorted to—as at Bedford and Doncaster—the observation will more particularly apply. The engine then raises from time to time at a small expenditure of power, the quantity of solid matter which is screened out of the sewage, and which is removed rather to prevent the valves of the pumps from being clogged than from any other obligation. Where the sewage is discharged by simple gravitation and is of an ordinary character unaffected by trade refuse and road detritus, the screening required at the sewer mouth before the sewage passes on to the land by the delivering conduit, is a very simple matter. It is, in fact, hardly necessary to speak of tanks at all, for the quantity of solid matter intercepted by the strainer is comparatively small. Screens made of wattles or trimmed bushes are very effective.

Sluice Chambers.—Where the sewage, after having been delivered to the highest point, is intended to pass on to land at lower levels, underground pipes may still be used with the help of sluice chambers and overfalls, at the former of which the sewage is divided and passes into the carriers for distribution through apertures graded in size by the engineer to the area to be watered. Sluice chambers are necessary wherever the sewage has to be regulated for distribution. They are of different forms and characters, and should be designed with special reference to the extent of surface to be watered. Some stoneware valve chambers with wooden sluices are made and are occasionally found useful. (See Figs. 129 and 130.) Metal valves in stoneware outlets and stops are also made by Doulton and Co. (See Figs. 131 and 132.)

The *distributing carriers* themselves may generally be formed in the ground, following such courses as its configuration will dictate. They must be laid with a sufficient fall to carry the sewage from end to end, and this will depend upon the nature of the soil and the distance to be reached. The work of forming these earth carriers will be done by the waterman, though the engineer in the first instance will probably lay them out.

Figs. 133 and 134 show half-round pipes, which are sometimes advantageously adopted, and Fig. 135 a slit pipe, which I believe has been occasionally used with good effect.

By the use of stops of metal or wood, the sewage travelling along the carriers is diverted in the direction desired, the skill of the waterman being proved by the evenness with which the sewage is supplied to the slopes so as to effect absorption without waste. The narrower the space to be fed the less will be the chance of waste, as was very satisfactorily shown at Bretons, by Mr. Hope, V.C., who

adopted slopes 20 feet wide. But against this advantage it must always be borne in mind that with a multiplicity of distributing channels labour is increased, and some loss of land, though not much, is occasioned.

Modes of Distributing Sewage.—In irrigation there are several modes of distributing the sewage over the surface. We have become familiarised with three methods, which are termed—the catch-water system, the pane and gutter system, and the bed system.

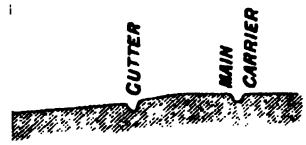
(4.) *The Catch-Water System.*—This system is almost sufficiently explained by its name, and a glance only at Fig. 1, Drawing XVII., will serve to stamp upon the mind the right impression. It consists of a series of distributing carriers following contour lines one under the other, with just sufficient fall to carry the sewage forward. These carriers not only serve, with the help of stops, to distribute the sewage over land immediately below them, but they act as channels to intercept—that is, to "catch"—the water which may flow off the land immediately above. By thus catching the overflow, the sewage may be several times applied, and Mr. Morton, one of the highest and best esteemed authorities on the subject, speaks very favourably of the system upon the ground that what is not absorbed by the soil of the first slope flows on to the second, and thence on to the third and fourth as the case may be, until it entirely disappears. I do not regard this mode of application with the same amount of favour, though with undulating surfaces it is often the best if not the only means that can be adopted. My objection consists in the fact that the sewage to be applied to any given space cannot be economically regulated, and that the quantity and strength of the sewage passing off as the tail water of one slope to become the head water of another must depend upon several conditions over which the irrigator has no control. It will often be found that the whole of the sewage is not absorbed even in free soils, but a portion finds its way from the surface of the lowest terrace into the receiving outfall stream. The catch-water system of distribution is much better suited to Italian rye-grass than to any other crop, inasmuch as when grass roots cover the surface to give it a matted condition, the sewage can pass over it with less disturbance of the soil. With the stiffer descriptions of land, however, the sewage will pass from one surface to another without being absorbed, especially in wet weather, and will ultimately get into the outfall stream, let the waterman do what he may.

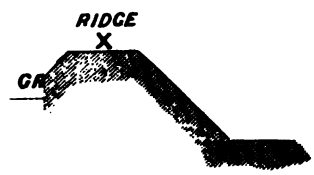
(5.) *The Pane and Gutter System.*—The system of distribution

TREATMENT & DISPOSAL OF SEWAGE.

Drawing XVII.

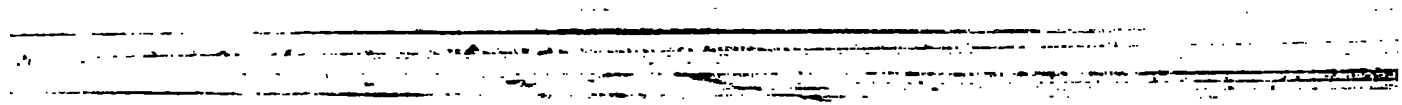
ICE FOR
ON.





ach Ridge at ×

BAILEY DENTON, SON, & NORTH.
22, Whitehall Place, LONDON.



called the pane and gutter arrangement is simply a wide bed, with but comparatively little fall, fed by sewage from the head of the slope by gutters traversing its face in such a manner as to allow of even distribution. These gutters, formed in the ground by the waterman, are sometimes laid out on the catch-water principle, whereby the sewage is distributed on one side only, and sometimes by courses following ridges, the sewage being distributed on both sides. This system allows of a considerable amount of waste, and where the panes or beds are large, with an uneven surface, sludge is collected and pools of sewage are formed which operate very disadvantageously, the farmer being tempted by the ready absorption of the sewage to "get rid" of much more than satisfies vegetation at the risk of impurity of effluent and the creation of a nuisance. It is upon these beds that the large quantities of sewage I have spoken of—15,000 to 20,000 tons—are swallowed up, and as long as there is no special provision of filtration areas to be used intermittently as a means of disposing of any excess of liquid, the practice may be tolerated, though the effect will be to prevent any profit being made.

(6.) *The Bed System.*—The bed system consists of lands laid out in the ridge and furrow form in parallel lines (see Fig. 2, Drawing XVII.) of greater or less length. The sewage is distributed over each land by a carrier or gutter running along the ridge and so shaped that with the aid of stops the sewage shall flow out of it evenly in a quantity sufficient to cover each side-slope. These lands are formed in two ploughings by throwing up the "rown" to the height required to give the necessary fall from ridge to furrow and following with the harrow or rake to gain a regular surface for the sewage to flow over. The stops are placed directly across the ridge-carrier, and the exact quantity the waterman should aim at giving to each side slope is just that which it will absorb when passing from the ridge to the furrow. When this watering is effected without much waste by supersaturation of the higher part, it may be said to be effected as economically as possible. The overall width from furrow to furrow, and the height of the ridge above the furrows, is regulated, as already stated, by the degree of porosity that the soil possesses. The width may vary from 30 to 150 feet, and the inclination of the surface slope from 1 in 25 to 1 in 150. The inclination given to the carrier, like that given to the side slopes, will also depend upon the degree of the porosity of the soil.

The experience I have gained in intermittent filtration leads me

to believe that where in irrigation the object is to secure an even distribution without waste of the valuable liquid, the sewage should not pass over the surface but should be run down furrows between narrow ridges formed by hand, or with the double mould-board plough;—like ridges formed when potatoes are well ridged up or when land is laid up into high "bouts" for the winter's weathering. Crops are grown on the ridges without any loss of land, as the furrows occupy only that space which is necessary to divide the rows of plants if a large yield is aimed at (see Figs. 3 and 4, Drawing XVII.). When the crops are removed the narrower ridges are split with the double mould-board plough and the whole field laid flat again, fit for the growth of cereal crops without liquid sewage. The suspended matters which have been deposited in the furrows are thus covered over with soil and form a very good dressing in itself for either wheat, oats, or pulse. This arrangement of narrow ridges is of course inapplicable to grass crops, but it is especially suited for roots and vegetables, as it allows the sludge of sewage to deposit itself with regularity in the furrows while the liquid sewage is occupying them, and this is done without either sludge or liquid touching the plants growing on the ridges. A perfect mixture of the sludge with the soil is obtained, which, as before explained, conduces to the improved filtering capabilities of the soil. In the "irrigation" carried out on the plains of Gennevilliers with the liquid sewage of Paris, this principle of arrangement is adopted in a successful manner. In a report addressed to the Minister of Public Works the method adopted is thus described:

"La répartition sur le sol se pratique à l'aide de raies séparées par des billons plus ou moins larges; ces raies se tracent: en plein champ, à la charrue; dans les parcelles passées à l'état de jardin, à la bêche et au cordeau.

"Les plantes poussent sur les billons: leurs radicelles seules vont chercher l'humidité et l'engrais au voisinage des rigoles; les parties vertes des plantes ne sont jamais touchées par l'eau d'égout. En automne et en hiver, il est quelquefois procédé à de vrais colmatages par submersions partielles des pièces à fumer, mais le plus souvent l'engraissement du sol dépourvu de végétation se fait également par rigoles et imbibition. Les quantités d'eau d'égout absorbées par les terrains de la plaine de Gennevilliers se sont élevées depuis 1869 à plus de 18 millions de mètres cubes, savoir:

	Mètres cubes. Nombres ronds.
1869	650,000
1870	810,000
1871 (Guerre et Commune)	
1872	1,500,000
1873	7,200,000
1874	8,000,000
Total . .	18,160,000

"Les doses annuelles à l'hectare ont varié de 50,000 à 100,000 mètres cubes."*

By reference to Figs. 3 and 4, Drawing XVII., the mode of distribution by furrows will be understood. It is the *reverse of ordinary bed cultivation by "lands,"* inasmuch as the fertilising liquid reaches the roots of the plant by lateral absorption instead of vertical descent. The width of the ridge may vary, sometimes partaking of the character of an asparagus-bed, and sometimes of a well-formed surface prepared for drilled mangolds.

It cannot be too well understood that, however well land may be laid out to receive sewage, the amount of profit or loss will depend upon subsequent treatment and control, and that failing to let the land when sewaged to a responsible tenant, it is far better for local authorities not to trust to the collective knowledge of a Board, consisting of many members and subject to frequent change, for its management, but to engage the most practical man they can find to act for them.

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* "The distribution over the soil is made by means of furrows separated by ridges more or less wide. In the fields the furrows are made by the plough; in the allotments used as gardens by the spade and the line. The plants grow on the ridges. Their roots only grow downwards and seek moisture and manure in close contact with the furrows. The green parts of the plants are never touched by the sewage. In autumn and in winter the manure (sludge), in a semi-dry state, is spread upon the lands, but the most frequent manuring of the soil when free of vegetation, is effected by means of the furrows and absorption. The quantity of sewage absorbed by the land of the plain of Gennevilliers has increased since 1869 to more than 18 millions of cubic metres. *e.g.*:

	Cubic Metres. In Round Numbers.
1869	650,000
1870	810,000
1871 (War and Commune)	
1872	1,500,000
1873	7,200,000
1874	8,000,000
Total	18,160,000

The annual proportions to a hectare have varied from 50,000 to 100,000 cubic metres."

CI.—Intermittent Downward Filtration. This process, to which reference has already been frequently made (Section LV.), was suggested by Dr. Frankland in the first report of the Rivers Pollution Commission (1868)—of which commission he was a member—dated the 18th February, 1870. In that report it is said that with a suitably constituted soil, well and deeply drained, nothing more would be necessary than to level the surface and divide it into four equal plots, each of which in succession should receive the sewage for six hours. "In this way," the Commissioners state, "the sewage of a water-closet town of 10,000 inhabitants could at a moderate estimate be cleansed upon five acres of land if the latter were well drained to a depth of six feet." "Such a filter is not a mere mechanical contrivance: it is a machine for oxidising, and thus altogether transforming, as well as for merely separating, the filth of dirty water. A field of porous soil irrigated intermittently virtually performs an act of respiration, copying on an enormous scale the lung action of a breathing animal, for it is alternately receiving and expiring air, and thus dealing as an oxidising agent with the filthy fluid which is trickling through it. To this chemical property must be added another cleansing agency—the actual aptitude for certain dissolved impurities in filthy water, which soil owes both to general surface attraction and to the chemical affinities which some of its ingredients possess." "A sufficient extent and depth of porous soil, having periodical intervals of rest during which the soil drains itself and becomes refilled with air, certainly must be the best possible strainer, oxidiser, and filterer of water containing nauseous organic impurities, both suspended and dissolved." The Commissioners had by sundry experiments found that a cubic yard of aërated soil would satisfactorily cleanse, up to the standard of purity they had proposed for water admitted into running streams, from $4\frac{1}{2}$ to 10 gallons of sewage each 24 hours according to the character of its constituents; and they stated that even when the rate of filtration amounted to 12·4 gallons per cubic yard in 24 hours, the sewage was greatly ameliorated, though not quite satisfactorily cleansed.

While propounding these views, however, the Commissioners thought it their duty to warn the public in emphatic terms, that there were "*three formidable objections*" to the general adoption of this process: "(1) it was entirely unremunerative; (2) the whole of the manure ingredients of the sewage would be absolutely wasted; and (3) the collection of solid fæcal matters upon the surface of the soil, with no vegetation to make use of them, would probably give rise to a formidable nuisance, especially in hot weather:" and these

words were regarded by many persons to amount practically to a condemnation of the process.

It was very shortly after the issue of this report, namely, in June, 1870, that I was appointed by the Lords Justices of Appeal in Chancery to devise a means of preventing, temporarily, the pollution of the River Taff by the sewage of the district of Merthyr Tydfil, and as the example there afforded has had some influence upon the sewage question throughout the country, I shall be pardoned if I explain how I came to risk my own reputation by adopting the suggestion of Dr. Frankland in spite of the objections he himself had raised to it. A long and active employment in land-drainage works in different geological formations had led me to observe, not only the rapidity with which water would pass through an aërated soil however closely consolidated, and the extraordinary clearness which distinguished the water issuing from underdrains when deeply laid in such soils, but that the proportion of the space occupied by air or water in all soils, however they may vary in their constituents, was very much more than was generally supposed. It had further satisfied me that vegetation would grow on any soil however wet at one time, if by underdrainage the water was made to give place to air with freedom. From these observations I concluded first, that Dr. Frankland's views as to the cleansing powers of soil were correct, second, that the absorbent powers of aërated soils were immense, and, last, that his anticipations in the shape of the drawbacks he specified were to be overcome. I did not therefore hesitate to recommend to the Lords Justices of Appeal the adoption of intermittent filtration through natural soil as a means of purifying the sewage of Merthyr Tydfil, modified in a manner I will explain to prevent the "three formidable objections" which Dr. Frankland had anticipated.

It has been already stated that the Rivers Pollution Commissioners, upon the strength of their laboratory experiments, had laid it down that the sewage of 3300 people might be cleansed up to the standard suggested by themselves by filtering intermittently through an acre of suitable soil. To remove all doubt as to permanency of effect, and to secure the growth of crops on the surface, I suggested (see Section LV.), first, that instead of having only one area to be in constant use, three areas of equal extent should be provided, each capable of cleansing the whole of the sewage daily; second, that these areas should be laid up in ridges and furrows and used for the purification of the sewage by running it into the furrows for one year only at a time, so that each of the three areas in its turn should be free from sewage (except on occa-

sions of excessive rainfall, &c.) for two years in succession and be devoted to full plant growth; third, that on the area in use crops of vegetables of a succulent character should be grown on the ridges so elevated above the intervening furrows that the plants should stand well above any sewage occupying the furrows; and fourth, that the area in use should be subdivided in accordance with Dr. Frankland's recommendation, so that one-third or one-fourth of the sewage should be applied for a fixed period every day to each subdivision. Thus it was intended that there should not only be an interim of two years out of three, but an intermittency of application each day. This would result in making one acre cleanse the sewage of 1,100—or as I have said, in round figures, 1,000—persons, on an average of three years, though for the single year in which it was used it would do the full work or duty expected by Dr. Frankland, relieved only at extraordinary wet times, when some of the sewage would be applied to the two other areas. It was this modification of Dr. Frankland's suggestion that I proposed to the Lords Justices of Appeal, and which being sanctioned by them was adopted at Merthyr Tydfil. It is this modification, too, which is now generally accepted by sanitary engineers as "intermittent downward filtration" wherever the principles enunciated by Dr. Frankland have been practically recognised.

It should here be observed that intermittent downward filtration can hardly be said to mean the application of any determined or fixed quantity of sewage to a certain area of land, inasmuch as there must always be a considerable variation in the character of the soil, the depth of the underdrainage attainable, and other conditions. It should therefore be understood that when Dr. Frankland speaks of the application of the sewage of 3,300 persons to an acre as the proportion resulting from his laboratory experiments, and I refer to the limit of 1,000 persons to an acre, it is considered that the land will be suitable, that it will generally be aërated by underdrainage quite two yards deep, and that the sewage will be applied in precise quantities intermittently.

Let me remind you of the difference between surface irrigation and intermittent downward filtration. With the general admission now made that underdrainage is essential wherever sewage is applied to the surface of land, "wide irrigation" means the distribution of sewage over as many acres as it will wet without supersaturation, having in view a maximum growth of vegetation from the amount of sewage applied; any departure from this, resulting in excessive application, being a waste of fertilising matter which is

inconsistent with economical farming. Intermittent downward filtration is the concentration of sewage at short intervals, on as few acres of land as will absorb and cleanse it, without excluding the production of vegetation at the same time.

In the absence of a proper provision for *intermittency of application*, filtration soon loses its precise character and is attended by results as unsatisfactory as the present utilisation of sewage by irrigation on the broad scale.

(1.) *Suitable and Unsuitable Soils.*—Upon this point it would be desirable, if possible, to speak in positive terms; but the experience gained of a process so recently brought into practice is necessarily limited, and it would be rash to declare decisively what soils perform the duty of purification with the best and most lasting effect, and what soils are altogether unsuitable. There is no doubt that the most perfect cleansing of sewage is effected by the use of evenly comminuted soils, consisting of a large proportion of fine gravel and sand, with a much less proportion of clay,—but percolation may be too slow as well as too rapid. The freer the soil the more rapidly is the sewage absorbed, and the more readily it filters through it to the drains, and it may be expedient to take land of this character rather than that of the denser kinds, even if the purification be less perfect. As we gain experience, however, the most open (coarse) soils will give way to the more compact (finer) soils in filtration as in irrigation.* Clay soils, for the reasons already given in speaking of surface irrigation, are to be avoided, for it is found that even after the most careful underdrainage, clays are liable to crack with a dry atmosphere and to swell with a wet one and to allow of the passage of liquid sewage from the surface down to the drains. If, therefore, it is absolutely necessary to have recourse to clays they should be deeply subsoil-ploughed or hand-trenched—sometimes to a depth of two or three feet—and, if very dense, they should be mixed, as already pointed out, with burnt earth, cinder-ashes, chalk, sand, or any

* "I take it for granted that the more finely comminuted the soil, so as to completely break up and divide the sewage as it passes through it, the more perfect will be the oxidation, and that no one will deny that the action of air and water upon clays is to divide the silicates in combination with alumina or pure clay, into the smallest possible atoms, if protected from unequal atmospheric influences. I take it for granted, too, that those soils that have the greatest power of seizing fertilising substances will be more effective in cleansing sewage than soils which, with an equal degree of fineness, have not the same power. Clays, I believe, are known to have the power of retaining fertilising substances in a much greater degree than sands and gravels, although the powers of absorption in the latter may be greater. It is for these reasons that I consider loamy soils, in which clay forms a part, are those which, if properly treated by drainage and deep surface cultivation, are capable of becoming better filters than sandy and gravelly soils. I do not mean to say that I should select a stiff clay—that would be ridiculous."—"THE SEWAGE QUESTION," by the Author.

other ameliorating substances. This work is necessarily very e
pensive, and, on that ground, clays should in no case be resort
to where soils of a freer description can be obtained, for it m
be often observed that as soon as a sanitary authority is led
believe that too much money is being expended, the treatment
made less effective, and the best intentions are frustrated.

(2.) *Underdrainage.*—Leaving out of consideration the adapt
tion of clays to the process of intermittent filtration, the unde
drainage of suitable soils, though an operation requiring extren
care in execution, is one that may be readily described.

The drains to keep down the level of subsoil water in
free soil should be deep and few. It is desirable to have as gre
a depth of filtering material between surface and drains as possibl
because the greater the depth the more perfect the effect and t
fewer may be the drains. On referring to the filtration areas adopte
at Kendal (see Drawing XVIII.) the engineer will see how the sever
plots into which the areas were divided were laid out. These plo
are divided by slight banks which prevent any overflow of sewag
from one plot to another, and serve as barrow-paths for the r
moval of the produce. Under each of these banks there is a drai
and as the object of the banks is to prevent overflow, so they a
also as bars to the passage of sewage over the drains. In free soi
it is seldom necessary to multiply the drains beyond the numb
adopted at Kendal. In many cases a much less number will suffice

It is desirable, where it can be arranged, to have the drain
sufficiently deep to afford effective aëration to a depth of six fee
and I am of opinion that to secure this the drains should be some
what deeper—say a foot if possible. Then under every square yar
of surface there will exist two cubic yards of aërated filtering ma
terial, giving 9680 cubic yards per acre—say, 10,000 yards. Thi
arrangement secures the best result; and at the same time it facilitate
calculation, every cubic yard having a cleansing power varying fron
4 to 12·4 gallons of sewage per diem. Hence it follows that a singl
acre drained so as to give six feet of aërated soil above the water o
attraction, will purify "sewage-proper" in quantities varying from
minimum of 40,000 gallons up to a maximum of 124,000 gallons.

It need hardly be pointed out, that in those cases where the deptl
of drainage is perforce of physical circumstances reduced to less tha
six feet, which I have taken as a standard depth, the superficial exten
must be increased in proportion as the depth of underdrainage i
diminished, in order to secure the necessary quantity of filtering
material for purification.

TABLE showing the Quantity of Land of Different Characters required to cleanse certain Quantities of Sewage, allowance of One Foot being made for Capillary Attraction.

SEWAGE TO BE DISPOSED OF DAILY.		VERY FREE GRAVELLY. 4 Gallons of Sewage to each Cubic Yard.				FREE-SANDY. 7½ Gallons of Sewage to each Cubic Yard.				LOAMY FREE SOIL. 10 Gallons of Sewage to each Cubic Yard.			
		Depth of Drainage.				Depth of Drainage.				Depth of Drainage.			
		4 Feet.	5 Feet.	6 Feet.	7 Feet.	4 Feet.	5 Feet.	6 Feet.	7 Feet.	4 Feet.	5 Feet.	6 Feet.	7 Feet.
gallons.	cubic feet.	acres. dec.	acres. dec.	acres. dec.	acres. dec.	acres. dec.	acres. dec.	acres. dec.	acres. dec.	acres. dec.	acres. dec.	acres. dec.	acres. dec.
5,000	802	·258	·193	·154	·129	·137	·103	·082	·068	·103	·077	·062	·051
6,000	962	·309	·232	·185	·155	·165	·124	·099	·082	·124	·092	·074	·062
7,000	1,123	·361	·271	·216	·181	·192	·145	·115	·096	·145	·108	·086	·072
8,000	1,283	·413	·309	·247	·206	·220	·165	·132	·110	·165	·124	·099	·082
9,000	1,444	·464	·348	·278	·232	·247	·186	·148	·124	·186	·139	·111	·093
10,000	1,604	·516	·387	·309	·258	·275	·206	·165	·137	·206	·155	·124	·103
20,000	3,209	1·03	·774	·619	·516	·551	·413	·330	·275	·413	·310	·248	·206
30,000	4,813	1·54	1·16	·929	·774	·826	·620	·496	·413	·620	·464	·371	·310
40,000	6,418	2·06	1·54	1·23	1·03	1·10	·826	·661	·551	·826	·620	·496	·413
50,000	8,022	2·58	1·93	1·54	1·29	1·37	1·03	·826	·688	1·03	·774	·620	·516
60,000	9,627	3·09	2·32	1·85	1·55	1·65	1·24	·99	·826	1·24	·928	·742	·620
70,000	11,231	3·61	2·71	2·16	1·81	1·92	1·45	1·15	·964	1·45	1·08	·867	·723
80,000	12,836	4·13	3·09	2·47	2·06	2·20	1·65	1·32	1·10	1·65	1·24	·992	·826
90,000	14,441	4·64	3·48	2·78	2·32	2·47	1·86	1·48	1·24	1·86	1·39	1·11	·93
100,000	16,045	5·16	3·87	3·09	2·58	2·75	2·06	1·65	1·37	2·06	1·55	1·24	1·03
200,000	32,091	10·3	7·74	6·19	5·16	5·51	4·13	3·30	2·75	4·13	3·10	2·48	2·06
300,000	48,137	15·4	11·6	9·29	7·74	8·26	6·20	4·96	4·13	6·20	4·64	3·71	3·10
400,000	64,182	20·6	15·4	12·3	10·3	11·0	8·26	6·61	5·51	8·26	6·20	4·96	4·13
500,000	80,228	25·8	19·3	15·4	12·9	13·7	10·3	8·26	6·88	10·3	7·74	6·20	5·16
600,000	96,274	30·9	23·2	18·5	15·5	16·5	12·4	9·9	8·26	12·4	9·28	7·42	6·20
700,000	112,319	36·1	27·1	21·6	18·1	19·2	14·5	11·5	9·64	14·5	10·8	8·67	7·23
800,000	128,365	41·3	30·9	24·7	20·6	22·0	16·5	13·2	11·0	16·5	12·4	9·92	8·26
900,000	144,411	46·4	34·8	27·8	23·2	24·7	18·6	14·8	12·4	18·6	13·9	11·1	9·3
1,000,000	160,457	51·6	38·7	30·9	25·8	27·5	20·6	16·5	13·7	20·6	15·5	12·4	10·3
2,000,000	320,914	103·	77·4	61·9	51·6	55·1	41·3	33·0	27·5	41·3	31·0	24·8	20·6
3,000,000	481,370	154·	116·	92·9	77·4	82·6	62·0	49·6	41·3	62·0	46·4	37·1	31·0
4,000,000	641,827	206·	154·	123·	103·	110·	82·6	66·1	55·1	82·6	62·0	49·6	41·3
5,000,000	802,284	258·	193·	154·	129·	137·	103·	82·6	68·8	103·	77·4	62·0	51·6
6,000,000	962,741	309·	232·	185·	155·	165·	124·	99·	82·6	124·	92·8	74·2	62·0
7,000,000	1,123,198	361·	271·	216·	181·	192·	145·	115·	96·4	145·	108·	86·7	72·3
8,000,000	1,283,656	413·	309·	247·	206·	220·	165·	132·	110·	165·	124·	99·2	82·6
9,000,000	1,444,112	464·	348·	278·	232·	247·	186·	148·	124·	186·	139·	111·	93·
10,000,000	1,604,570	516·	387·	309·	258·	275·	206·	165·	137·	206·	155·	124·	103·
20,000,000	3,209,140	1,033·	774·	619·	516·	551·	413·	330·	275·	413·	310·	248·	206·
30,000,000	4,813,709	1,549·	1,162·	929·	774·	826·	620·	496·	413·	620·	464·	371·	310·
40,000,000	6,418,279	2,066·	1,549·	1,239·	1,033·	1,102·	826·	661·	551·	826·	620·	496·	413·
50,000,000	8,022,849	2,582·	1,937·	1,549·	1,291·	1,377·	1,033·	826·	688·	1,033·	774·	620·	516·

In order to bring the atmosphere to bear upon the subsoil and to limit as far as possible the uprising of water by attraction, an upright ventilating shaft is placed at the junction of drains. The shafts consist of pipes placed on end coming up to the surface, upon the top of which a grated covering is placed, in order that the air in dry times may enter and circulate through the under-drains. After a continuance of wet weather the "water of pressure" from higher ground will find its way into the areas, and the subsoil water will rise above the drains. The watch-holes tell the height of this rising subsoil water, which while reducing the aërated earth space compensates for the loss by increased dilution of the sewage effluent.

(3.) *Surface Preparation and Formation.*—To enable the soil to absorb and filter the sewage distributed over its surface in the interval of time within which it is expected to do its work, it is necessary to "rough level" the surface and break up by digging and trenching all land which in its natural state would not absorb the sewage with sufficient rapidity. Sometimes this work is best done with a plough. Generally hand labour will be found necessary, the depth of the trenching being governed by the natural density of the soil.

It is essential to continued purification that the sewage should be applied to each plot in an even manner. The width between furrow and furrow necessary to effect regular absorption will vary with different soils—those ridges that will maintain their batter when the sewage is passing down under different conditions of the atmosphere, being narrower than those which give way. I have made some ridges just wide enough for one row of cabbages or roots, others for two (see Drawing XVII., Figs. 3 and 4), and others again for three rows, and have always found before the season of growth has passed, that the leaves of the plants touched each other, and covered the furrows completely, with the eight or nine inches depth of sewage they periodically contained. I mention this in support of the statement already made, that the existence of furrows does not necessarily involve a loss of land nor a reduced production of vegetation. So far from the sewage being in too great a quantity to allow of the growth of suitable vegetation, it has been positively demonstrated that very heavy crops of both roots and cabbages have been produced in spite of the large doses applied, which at Merthyr, 1872, realised upwards of 40*l.* an acre.* By referring to the Table, "showing the money results of applying sewage to land" (in Section XCII.), it will be seen that the excess of *crop-return over expenditure*

* See evidence of Mr. Harpur, Question 2860 *et seq.*: Fifth Report of the Rivers Pollution Commissioners, vol. ii.

is greater in the case of intermittent filtration than in surface irrigation, where each occupy their proper limits of extent, and I am quite prepared to find that there is generally a greater "*acreage*" return from that mode of treatment, if carefully arranged, than from surface irrigation in proportionate areas. I shall not be surprised to find that three filtration areas of 10 acres each, making 30 acres, laid out to cleanse one million gallons of sewage daily, will yield a greater money return *per acre* than 300 acres of land forming an irrigation farm to cleanse the same quantity of sewage.

It is unnecessary to point out that the more level the land selected for the purpose the better it is suited for *downward* filtration. Not only is money saved in formation, but the distribution of the sewage is kept under better control. If the land has considerable slope it may still be requisite to lay it out in furrows, though the beds will then take the form of terraces at various levels. I should not despair of constructing a catch-water filter on ground of a very porous nature with a sharp inclination of surface.

(4.) *Delivering Conduits, Tanks, Sluice Chambers, and Distributing Carriers.*—Having described at some length these several objects when speaking of wide irrigation, I hardly think it necessary to say much more with regard to them here. The same remarks apply to the distributing works used for filtration as to those used for irrigation. As, however, the object of intermittent downward filtration is the cleansing of sewage by its *even* distribution and *uniform* absorption and infiltration, it is essentially the work of an engineer. I would refer you to the conduits and chambers used at Kendal, which are shown in Drawing XIX. as some proof of this. The practice I have spoken of as prevailing in wide irrigation, of running sewage into the lowest places or wherever it will travel in the absence of the waterman, is opposed to purification, and though dignified with the name of "intensified irrigation" is nothing else but very bad farming. Such slipshod work is inconsistent with well-devised filtration areas which should absorb the liquid distributed over their surfaces in the precise quantity in which the subsoil is intended to cleanse it. The *delivering* conduits, and the regulating chambers with which they are connected, should be most carefully devised and executed in a substantial manner so that they may be kept in perfect order. The *distributing* carriers being frequently disturbed, may for the most part be made in the surface earth—as in the case of wide irrigation—though half-round pipes or wooden or iron troughs may occasionally take their place with advantage. As first works those at Merthyr and Kendal were expensive, but since the Kendal work was executed, I have seen reason,

with increased experience, to adopt modifications which have reduced the cost without lessening efficacy, and I am able to say that the actual difference between the cost of works for intermittent filtration and those for surface irrigation is not so great as is generally supposed, and which for some reason or other has been greatly exaggerated. I have been particularly struck with the readiness with which the cost of the filtration works of Merthyr and Kendal have been published without explanation in official reports, &c., as if the object was to depreciate the process and not to put forth the truth with regard to the special facts which made those works more costly than may be found necessary hereafter.

As to *tanks*, the same observations that were made upon these appliances in the last section will apply here. In every case I think it desirable to act tentatively and not to embark into costly tank arrangements until it is known by actual treatment of the sewage as it is discharged from the outfall, and by trial of the soil which is to absorb and filter it, to what extent the suspended flocculent matters will be satisfactorily disposed of on the land, and what proportion of the heavier and bulkier substances must be intercepted by straining, screening or deposition, before it reaches the land.

(5.) *The Merthyr Tydfil Works described.*—It is more with a view of showing how intermittent downward filtration may advantageously take the place of wide irrigation altogether or be combined with it to enable sanitary authorities to fit the disposal of their sewage to the circumstances of their districts, that I recur to this case and propose giving a full explanation not only of the filtration works carried out by me in obedience to the orders of the Lords Justices of Appeal, but of the operations of the Local Board with respect to wide surface irrigation, to which they were pledged. A statement of the facts cannot fail to be interesting to all persons engaged in sewage disposal.

As early as in April, 1869, Mr. Harpur, the local surveyor, proposed, and the Local Board approved and submitted to the central authority, a scheme for utilising the sewage of the district by irrigation. The lands intended to be taken consisted of about 375 acres of land in the valley of the Taff, of which one plot of about 75 acres is situated in free soil under the hills at Troedyrhiew, within a quarter of a mile of the village of that name. The remaining 300 acres are situated outside the district, much lower down the valley, and the sewage is conducted to this land by an outfall sewer from the Troedyrhiew land. It was in consequence of the heavy character of the irrigation works, and the time that would be

taken to perfect them, that proceedings in Chancery were taken by certain colliery proprietors who were affected by the pollution of the River Taff, and who desired that the pollution should be prevented during the construction of the works, and my appearance on the scene with intermittent filtration was in consequence of my being appointed by the Lords Justices to effect this interim remedy.

The quantity of land that I suggested for this (temporary) purpose was 20 acres of free soil (part of the 75 acres) at Troedyrhiew, which I divided into four plots of about five acres each. Upon each of these plots it was intended that a fourth part of the day's sewage from a population of 30,000 persons,* should be distributed after it had been partially strained at the existing tanks. The whole of the 20 acres thus divided was intended to be drained seven feet deep, but owing to the work being imperfectly done this depth was not quite gained, and the drains may have to be relaid. The actual depth however gave two cubic yards of drained, but not perhaps perfectly aërated, soil for every square yard of surface. Thus every plot of five acres contained 48,400 cubic yards of filtering material capable, as it turned out, of cleansing the sewage at the rate of 10 gallons per cubic yard per diem, or 484,000 gallons each area.

The total dry weather outflow of the sewers of Merthyr varied at that time from a minimum of 700,000 gallons to upwards of 1,000,000 gallons per diem. This was increased in wet weather to upwards of 2,000,000 gallons per diem.

To convey the sewage from the sewers to the 20 acres involved the construction of a delivering conduit from the tanks forming the terminus of the sewers. It was of considerable length, and was of course available for the delivery of the sewage to the remaining 55 acres of land of the Troedyrhiew plot. The making of this conduit, the drainage of the land, and the preparation of the surface, took some time to perform, and it was increased by the fact that the work was so executed in the first instance, that I was called upon by the Lords Justices to take the work under my own supervision and rectify and complete it. I need hardly say that a long length of delivering conduit for the whole of the 75 acres and the re-execution of a considerable part of the drainage and levelling, increased the cost very much beyond what it would otherwise have been. I refer to this because this large outlay has been quoted as a reason why filtration should be avoided, and it is absolutely necessary, in the interests of sanitary science, that the facts should be known.

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* See evidence of Mr. Harpur, Question 5877, Fifth Report of the Rivers Pollution Commissioners, vol. ii.

I will also add, that although directing the works and responsible for their efficacy, I had nothing to do in selecting the workmen or materials, or in fixing the prices to be paid. All money matters were arranged by the local authority, who regarded my appearance as an intrusion, and were not very anxious for my success.

From the best information I can collect, I am led to believe that the actual outlay on the Troedyrhiew plot (75 acres), was 6,000*l.*, including the delivering conduit for the whole area, the preparation of 20 acres, and the subsequent laying out of the 55 acres for irrigation, and it is quite certain that if the filtration work had not been subject to the disadvantages to which I have referred, the cost might have been much less;* in fact, the whole 75 acres might have been drained and laid out for *intermittent filtration* for no greater sum than was unfortunately expended in the combined arrangement. The rent or annual charge for the 75 acres of land at Troedyrhiew, I was given to understand, would not exceed 375*l.* to 380*l.* a year. Now taking 6,000*l.* as the cost of preparing the 75 acres, and assuming that that amount will be repaid in thirty years at 6 per cent. the total annual charge upon the ratepayers of Merthyr if the expenditure had been confined to the 75 acres at Troedyrhiew would have been at this moment 740*l.* a year, or nearly 10*l.* an acre. The return of money from the crops raised from the whole of the Troedyrhiew farm, consisting of 75 acres, may be certainly taken to have reached 20*l.* an acre at the very least, owing to the demand for sewage produce being equal to the area under cultivation. I am thus particular in pointing out these facts because I do not think there is a shadow of doubt but that the 75 acres would have been sufficient, if properly laid out for intermittent downward filtration, to have disposed of the sewage of the whole district of Merthyr Tydfil for the next thirty years. This is not mere assertion: what was done with the 20 acres at Troedyrhiew while used alone, and what had since been done at Kendal, relieves the matter of all conjecture. Nor is there any doubt but that the yield of the 75 acres in roots, vegetables, and Italian rye-grass, for which there would have been a safe and certain market in the immediate neighbourhood, would have been ample to have secured at least 10*l.* an acre, or 750*l.* a year, after payment of all expenditure on labour, seeds, &c., and this return would have paid the rate chargeable on the district to meet the outgoing of 740*l.* a year. By this course of proceeding the ratepayers of Merthyr Tydfil might have been saved

* For confirmation of this statement see evidence of Mr. Harpur, Question 5910, Fifth Report of the Rivers Pollution Commissioners, vol. ii.

the rates they have now to meet, and sewage farming would not have another instance of failure recorded against it, which, in the interests of agriculture, is so much to be regretted.

To explain these remarks it is necessary to state that the total actual outlay in the purchase of land (315 acres), exclusive of the 60 acres of land held on lease, and in the execution of works, has been nearly 54,000*l.*, which, at 6 per cent. to repay principal and interest, involves a charge on the ratepayers of 3,240*l.*, amounting to 6¼d. in the pound on the rateable value of the district, irrespective of the loss in farming the larger area of land which the Board have now on their hands, and which may increase the rates very considerably.

> [The report of Messrs. Rawlinson and Read indicates that the total return has not reached 8*l.* per acre, showing a loss of 769*l.* a year. I commend these figures to the consideration of all those who would advise sanitary authorities to launch into sewage farming *on a large scale* in the present state of knowledge on the subject.]

That purification was gained by the intermittent filtration practised at Merthyr by 20 acres only, and could have been assured for a permanency by the use of the 75 acres, is shown by the analyses of several eminent chemists—Dr. Frankland, Dr. Russell, and Dr. Benjamin Paul.

The filtration works were completed and the effluent discharged in the autumn of 1871 (though a portion of the area had been in use since the spring of that year), when the amount of organic nitrogen found in the effluent water was shown to be very much less than the amount set forth in the standard recommended by the Rivers Pollution Commissioners (·3 of one part in 100,000 parts). The figures given by the chemists referred to, representing the decimal of one part in 100,000 parts, are as follows:

Dr. Frankland. Average of six samples taken from the middle of 1871 to the end of 1872 . . .	·032
Dr. Russell's analyses—1872. Average of winter and summer	·029
Dr. B. Paul's analysis—1871	·018

Since 1872 the filtration areas have been used in common with the rest of the land—*i.e.*, the 300 acres at a distance—purchased by the Board, and they unfortunately no longer afford any criterion

of what may be done by intermittent downward filtration when practised by itself at Merthyr. As they have, however, been continued in use from that time to this, in combination with surface irrigation, it is satisfactory to know from Mr. Dyke, the medical officer of the district, that there has never been any sign of clogging or over-saturation.

Mr. Jones, the chairman of the Local Board of Merthyr Tydfil, wrote me only a few months ago in the following terms:

"I also desire to disabuse your mind that the Board contemplates the abandonment of the filtration areas. It contemplates nothing of the kind, but looks upon them as being that which cannot be described better by any other term than the one you use, namely, a 'safety valve.' In fact, so satisfied is the Board with the principle of downward filtration as the purifier of a large quantity of sewage on a small area, that Mr. Harpur has just designed for the disposal of the sewage of a population outside our main drainage, according to that principle, and we are seeking for powers under a provisional order to obtain land compulsorily for that object. I may also add that we have it in view if the land we shall have acquired be found to be too limited for wide irrigation to lay out a set of filter beds on the Park Newydd Farm, which we have just bought."

And Mr. Dyke has declared, in a recent letter addressed to me, "as the result of close watching, frequent examinations of the areas and of the effluent water, and careful attention to the statistics of sickness and of death, that the mode of disposing and utilising sewage carried out at Troedyrhiew, is thoroughly efficient as a means of purifying sewage, quite innocuous in its operation, and that the effluent water is nearly pure; the only impurity being about half a part of nitrite of lime or of potass in 100,000 parts of water."

> [The reader of these remarks will find it interesting to compare them with those of the Committee appointed by Mr. Sclater-Booth on the same subject.] (See Report, p. 23.)

(6.) *The Kendal Works described.*—These works have been executed since the completion of those of Merthyr, *i.e.*, in the year 1873-4.

The population of the borough of Kendal was at that time 13,500, and the water supply 400,000 gallons per diem. The quantity of sewage diluted with subsoil water, irrespective of any increase during rainfall, amounted to a mean of 975,000 gallons per diem, the maximum being 1,800,000 gallons and the minimum 750,000 gallons. When the influx of surface water into the sewers

reaches its fullest amount the outflow of sewage from the town sometimes reaches 5,000,000 gallons daily, but no greater quantity than the maximum dry weather flow diluted with *subsoil* water can pass to the filtration areas owing to the existence of a storm overflow which comes into action as soon as the 1,800,000 gallons are reached. The sewage proper of the town (400,000 gallons daily) before dilution with subsoil water was perhaps as filthy as that of any town in England, for although out of 2727 houses only 450 had water-closets, the overflow from 1600 common privies was discharged into the sewers in addition to the liquid refuse of several woollen and carpet manufactories, tanneries, paper-mills, and marble works.

The corporation of Kendal before the end of 1872 had purchased the estate called Watt's Field, consisting of 66 acres of land, at a cost of 16,370*l.*, or about 250*l.* an acre. Of this only 16 acres were at a level to allow of the sewage being distributed over them by gravitation. The remaining 50 acres are high and undulating, and being close to the town are wholly unsuited for either irrigation or filtration. To utilise these 50 acres would have involved pumping, and therefore it was determined to appropriate the land to other purposes (I believe it has been contemplated to resell it in building plots), and use for sewage purposes the 16 acres alone.

> [These facts cannot be too well understood. See Report of the Committee appointed by Mr. Sclater-Booth, in which the case is very differently stated.]

When I was consulted in 1873, I recommended that 15 acres out of the 16 should be laid out for intermittent filtration, but the council of the borough having understood that Dr. Frankland had declared that one acre would purify the sewage of 3300 people, rejected my advice, and acted upon Dr. Frankland's view instead. They determined to have only five acres prepared, intimating at the same time that if afterwards it was found that the reduced area was insufficient, the local surveyor, Mr. Banks, could continue the work of which the five acres would be the example. Being desirous of testing the quantity of sewage that land would absorb, I did not hesitate to act upon these instructions, though I protested against them.

The straining and depositing tanks through which the sewage passes were in existence at this time, and formed no part of the work executed, which may be shortly described in the following terms. (See

Drawing XVIII.) The sewage after passing through the tanks is c veyed to the areas by a pipe conduit 21 inches in diameter having inclination of 1 in 1760. The areas were laid out in four plot $1\frac{1}{4}$ acres each, and these were sub-divided into smaller plots receive the sewage intermittently. The subdivisions were effec by raised barrow-paths (as already explained) intended to prev the overflow of sewage from one plot to another and to cover under-drains. Every drain is in fact covered by road or path standi well above the formation level so that the sewage can never tra over the drains. The underdrainage was effected at a sufficie depth to secure aëration six feet below the surface. The m outfall drain consisted of glazed socket pipes 18 inches in diamet The drains branching from the main drain are nine inches and inches.

At the junctions of the several drains with one another, verti shafts consisting of pipes standing on end, one upon another, wi iron grated covers, are provided. They serve for inspection as w as for aëration. The outlet of the main drain into the river is abo one foot above ordinary water level.

The several areas into which the five acres are divided are form into ridges and furrows, with just sufficient fall in the latter to car the sewage from one end to the other. The ridges are made different widths, and upon them grow one or two rows of vegetabl as may be considered best. (See Drawing XVII., Figs. 3 and 4.)

As to the precise quantity of land to which the sewage dilut with subsoil water has been applied, I will give it in the words Mr. Banks, who now has the areas under his control:

"The total area, including paths and carriers, devoted to t filtration beds, is $5\frac{1}{2}$ acres; but the area to which the sewage actually applied is 4A. 2R. 25P., divided into four ranges of bed three only of which, containing 3A. 2R. 0P., being used each twent four hours, the sewage running eight hours on to each in successio and the remaining fourth being used alternately with the others as reserve, and for change whilst working the crop."

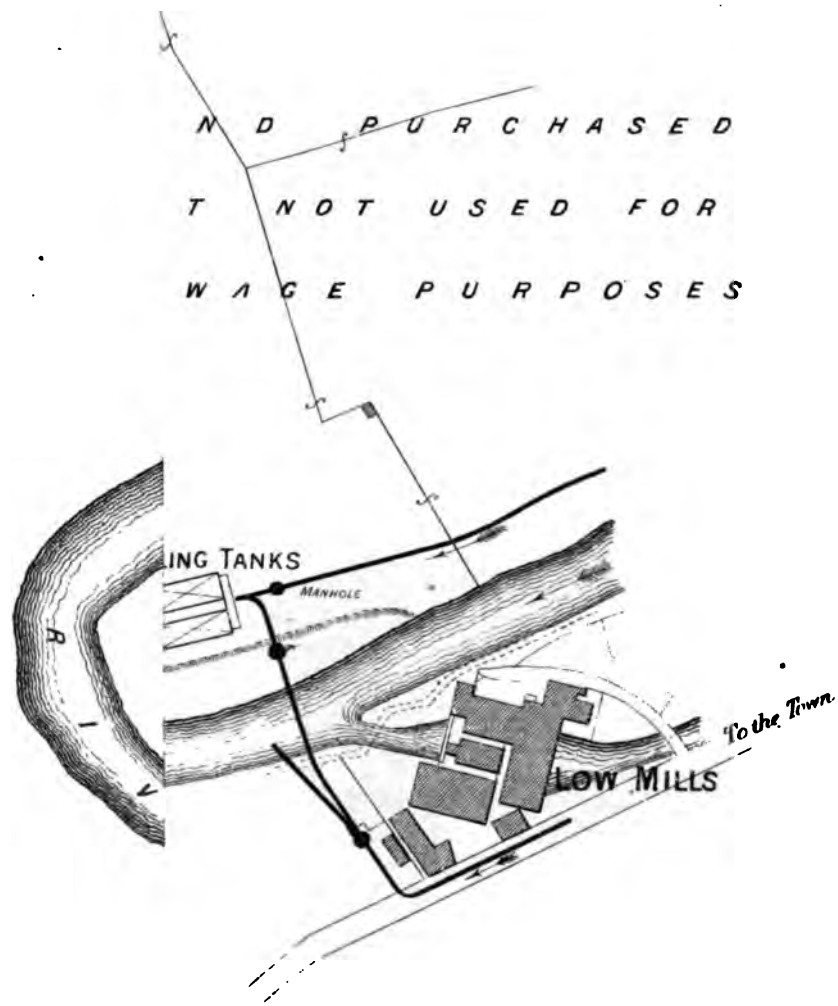
Of the effluent water from the under-drains of the filtration area Mr. Banks states:

"*Quantity.*—In ordinary weather, when the river is at a mediu level, the outflow from the under-drains averages one-third of th quantity of sewage delivered on the land, the remaining two-third being lost in the gravel. When the river is very low, the whole the sewage disappears in the gravel subsoil, and no effluent runs o into the river.

NT AND DISPOSAL OF SEWAGE.

Fig. XVIII.

FILTE



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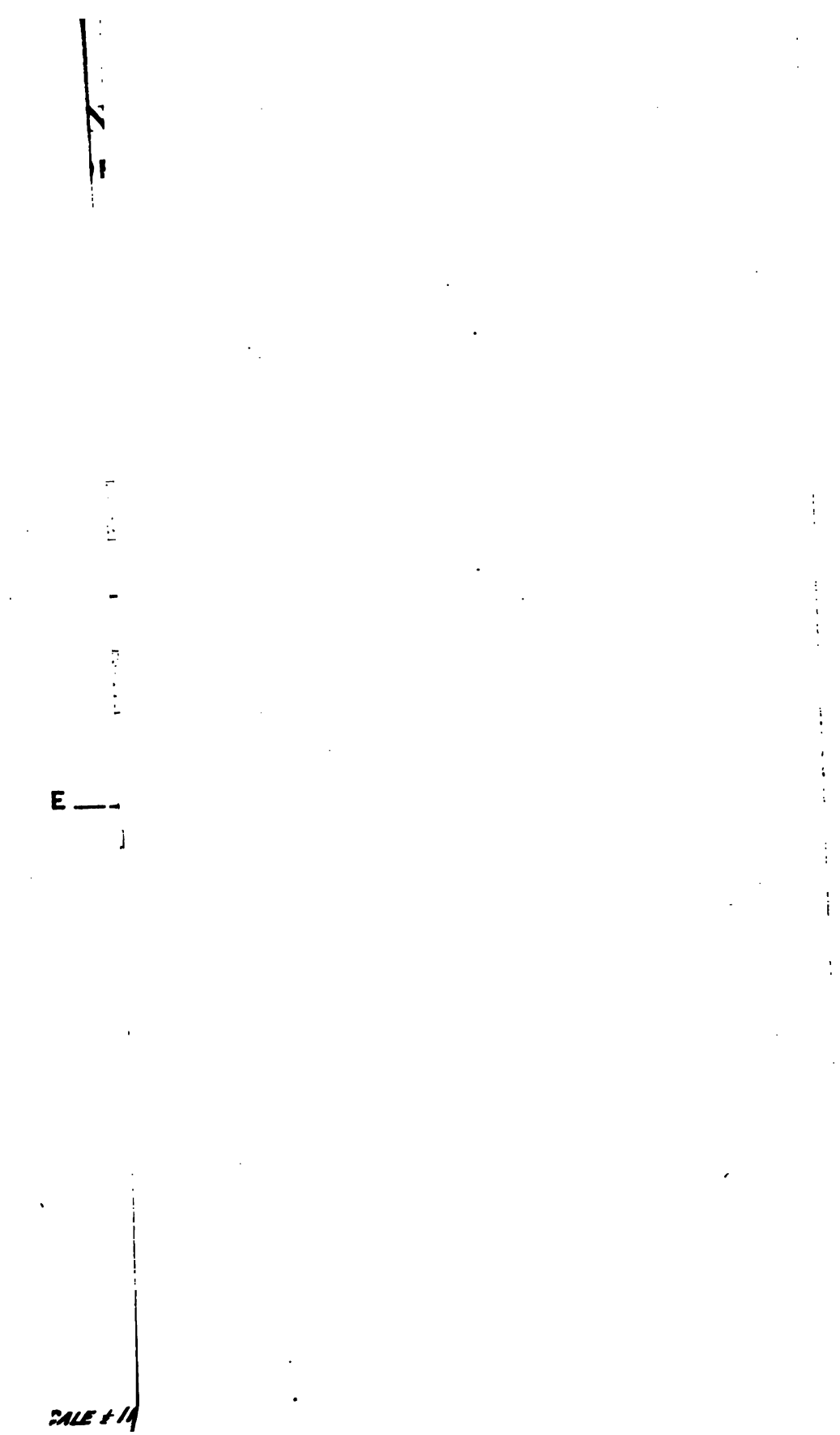
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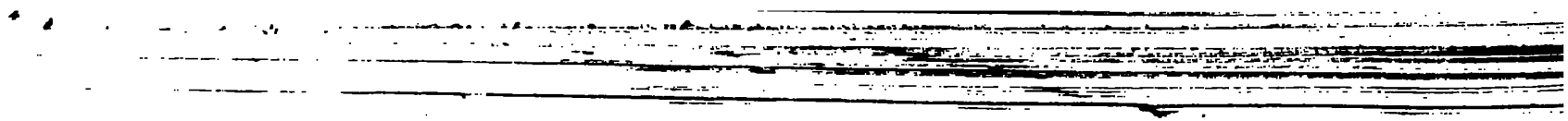


"*Quality.*—The effluent water from the areas is perfectly colourless and sweet; in fact, with the exception of a slightly brackish taste, is good, potable water, which I have drunk many a time."

The utmost quantity of diluted sewage which the Kendal areas were intended to cleanse was 1,000,000 gallons, though that quantity was often exceeded. The conduits, chambers, and carriers were made capable of conveying to and distributing over the land about 900 gallons per minute, or 1,296,000 gallons per day. Any difference between this quantity and the maximum quantity of 1,800,000 gallons brought down to the tanks by the outfall sewer has to find its way over the land outside the areas. The main delivering conduit was intended not only to serve the five acres already laid out, but to carry forward the sewage to the land on the north side to which the sewage may be hereafter applied. (See Drawings XVIII. and XIX.).

The sewage is distributed in the following way: Areas one, two, and three each take it in turns, two of them for six hours each during the day, and the third for the twelve hours of the night, when the outflow of sewage proper from the town is less in quantity and more diluted in character. By this means intermittency of application is secured, and the precise service of each area maintained. The fourth plot is held in reserve to be used when it is desirable to dry either of the other three plots and to spread on the ridge the solid matter that has deposited itself in the furrows. By raising the sluice belonging to one area and closing those of the others, the daily service is arranged with a perfect command over the sewage and the several areas. The notch-plates being all at one height the width regulates the proportion of sewage they admit to the divisions to which they severally belong. One plot containing a certain number of cubic yards, for instance, has a plate with a notch width to agree with its cubic contents, say, 16 inches; and this will allow the required quantity of sewage to pass through it, while another area of half the number of cubic yards will be served by a notch of a width of 8 inches. Drawing XIX. shows by sections of conduits and carriers the arrangements made at Kendal for distributing the sewage over the filtration areas.

The remarks I have more than once made on the advantages of *even distribution* and uniform absorption when resorting to filtration, will, I trust, have impressed my readers with the necessity of accuracy of design and precision of execution, and will have rendered it unnecessary to go into the details of costs in a case which, being only the second successful application of the process, cannot be

quoted as any criterion of future expenditure. Intermittent filtration, if it had been treated in the same slipshod manner in which surface irrigation has been practised, and by which sewage-farming has been reduced to failure, could not have survived a day in the face of the prejudice to which it has been subjected.

To be successful either in filtration or in irrigation the same amount of care must be given by the engineer in laying out the land, and by the occupier in distributing the sewage, and though the preparation of the ground in the former case may cost more than in the latter, it will be found in the result that true economy will be better obtained by a liberal expenditure of money on a moderate area, regulated by the circumstances of the case, than by a niggardly treatment of a large one. I feel bound to declare my own opinion to be that nothing has done so much to prevent success in the utilisation of sewage to land as the want of discretion in expenditure.

> [I must again refer the readers of these pages to the report of Messrs. Rawlinson and Read, and to the remarks therein made on the Kendal work, contenting myself with guarding them against the very remarkable way in which the case is treated, apparently with a view to make it appear costly and unremunerative.] (See also Section XCII. p. 264).

(7.) *The Cleansing of Trade Refuse.*—I have already particularly referred to the character of the liquid refuse discharged by different trades (Section LXXV.), and the tendency of public opinion and the Legislature to favour the admission of it into common sewers. The disposal and cleansing of the discharged contents of sewers when mixed with trade liquors is a point pressing very much upon sanitary authorities in certain districts, and must necessarily demand the earnest attention of the engineer.

Intermittent filtration through natural soil, or irrigation over a wide surface where a sufficient area can be obtained for the purpose, will be found all-sufficient for the cleansing of many kinds of trade liquids, though it may be necessary to subject certain other kinds to chemical treatment before they are distributed on land in any way. "Near Shepley, on land below the mill of Messrs. Barnicott and Kenyon, the whole of the soapy, greenish, greasy mill drainage is conducted by a contour carrier along the upper edge of a steep grassy bank, down which it is made to trickle at intervals by means of a roughly-managed set of stops in the carrier, reaching

at length a flatter plot of grass, not more than an acre or two altogether, where it disappears." "At Messrs. John Foster and Sons' mohair and alpaca works, at Queensbury, near Halifax, the liquid refuse which escapes is carried on to land below the factory, and reaches the natural watercourse after the cleansing effect of irrigation." "At Messrs. Townend's works also, at Cullingworth, near Bingley, the drainage of a large mill, mingling here however with that of the village, flows on to some hill-side grass land and produces a large growth of grass before finding its way into the stream. The result here, if not attributable wholly to the fertilising effect of dirty wool washings, at any rate proves that such dirty waters, with the spent liquors from dye works, may be discharged into ordinary house sewage without injury to its value as a manure." "At Guiseley, near Leeds, the Ings Mill (Woollen) Company have attempted to cleanse their offensive drainage water, first by the use of successive subsidence tanks arranged round the factory . . . . and then by letting the final overflow trickle roughly over eleven acres of grass land before reaching the watercourse." "In all these cases the management is of the roughest kind, and in some instances the success was far from perfect, but this ought not to discourage the attempt to apply the agricultural remedy wherever it may be available for the abatement of any nuisance arising from mill drainage." "At the Jackroyd Dye Works, near Halifax, a system of filtration and rough irrigation has been adopted with considerable success."

These extracts are taken from the third report of the Rivers Pollution Commissioners (1868). In their fourth report, the same Commissioners, speaking of a series of experiments made on the cleansing of waste liquors from woollen works by intermittent filtration through earth, say that in that process "the woollen trade has in its hands a process easily available, except in large towns, for the purification of its foulest waste liquors. The analytical table" (given by the Commissioners) "shows that during a trial extending over nearly a year, it was only on rare occasions that the impurities in the effluent water approached the limits suggested by us as those beyond which liquids shall be deemed polluting and inadmissible into streams." In speaking of calico works, the Commissioners say, "in calico, as in woollen works, there are, therefore, two systems for the prevention of river pollution available, the choice between them depending upon the situation of the works. 1. Discharge into town sewers. 2. Intermittent filtration, aided, if need be, by the evaporation of a portion of the foul liquids

in the ashpits of furnaces." "The first of these systems is obviously available for works located in towns; the second is applicable to those situated in the country; and both are entirely unfettered by any patent rights whatever." "As in the woollen and calico industries, so in linen, jute, and paper works, the first step in the application of a remedy for pollution is the adoption of the principle of separation of the most filthy liquids from the general drainage of the factory. For instance, in the bleaching of linen and jute, the waste liquor of the second boiling with alkali should be fortified with fresh alkali, and then used for the next first boiling. It will then probably repay the cost of evaporation to dryness and extraction of the soda which it contains, an operation which is now generally performed upon a similar waste liquor produced in paper mills. The waste chloride of lime and sulphuric acid liquors should be mixed together and submitted to intermittent filtration. The polluted water in which flax has been steeped, can also be readily purified, like woollen and calico waste, by irrigation or intermittent filtration." Of linen and jute bleach works, the Commissioners remark that they "appear to be almost invariably situated in the country, and there can therefore be but little difficulty in obtaining the small area of land required for the purification of such foul liquids as are not evaporated to dryness for the recovery of soda."

The Commissioners point out, too, that which actual experience has made apparent, that the addition of town sewage to trade liquors is an advantage inasmuch as the mixture of the two makes them more applicable to land than trade liquors would be alone.

I must refer you back to a letter I read when treating of the mode of disposing of the sewage of private dwellings, which I was fortunate enough to receive from Baron von Liebig just before his death (see Section LV.), for confirmation of the opinion of the Rivers Pollution Commissioners, that land can be advantageously used for the cleansing of trade liquid refuse. In that letter the Baron states that for some years past the best use has been made of the intermittent filtration principle in the sugar manufactory of Herr von Rath, in Silesia, adding that "all the water that had been used in the factory, and generally all waste and foul liquids, are discharged upon a well-drained piece of land close at hand, and the filtered effluent water is collected in a well." He states, too, that the "water is pure and clear, and *is again raised by a pump and used in the factory as fresh water.*"

From the experience gained at Kendal, with its factories, it may

be assumed with certainty that intermittent filtration will cleanse trade refuse liquid mixed with the ordinary sewage at the rate of at least 100,000 gallons to an acre of land appropriately prepared, while in dealing with isolated factories the special suitability of the process consists in the power it affords of cleansing large quantities of used liquid without any chance of nuisance and with every probability that the liquid will be made fit for use again. Indeed, the practice of Herr von Rath, of concentrating the underdrainage water from the land to which the foul liquid of his factory had been applied, and then raising it for re-use, may in many cases be very favourably adopted in this country. In the valley of the Calder, for instance, the soil of which is extremely porous, the land through which the sewage would filter may be drained into tanks or wells from which the effluent may be raised by steam power for use for trade purposes after the foul and noxious matters have been filtered out of it. In towns that have no general trade to characterise them, but in which there exists one or more trades discharging obnoxious liquid refuse—such, for instance, as that discharged from a tannery or a brewery—it would appear only just that the individuals who specially benefit by those trades should adopt a separate mode of disposal, or contribute more largely to the rates than the rest of the townspeople. If separate treatment be preferred, intermittent filtration will be found the least objectionable and the least costly process to adopt.

(8.) *General Remarks with reference to Works in progress in different parts of the Country in which Intermittent Downward Filtration is adopted wholly or partially.*—In the face of prejudice, based on the supposition that land may be readily supersaturated by repeated applications of liquid however well it may be underdrained, and that the pores of the soil will become clogged with flocculent matter whatever the ingredients of that matter may be (see Sections XCIII. and XCIV.), intermittent downward filtration has made considerable progress, and has found advocates amongst those who at first opposed it (see description of the Merthyr works in this section). This progress has been made notwithstanding the oft-repeated statement that to prepare land for filtration is a costly operation,—the effect of which has been, not to prevent the adoption of the process, which would appear to be the object, but to lower the quality of the intended works, and to cause them to be executed in a manner which cannot fail to bring discredit on the process itself. This will be due, not so much to the incompetency of the persons carrying out the works as to the influence of those who have unfortunately led sani-

tary authorities to believe that intermittent filtration is simply *intensified irrigation*, than which it is hardly possible to utter a more misguiding precept; intermittent filtration being, as I have before said, a carefully devised work, which should stand the test of all time, while intensified irrigation is only another term for the wasteful acts of a bad farmer. (See Section C.)

It is doubtless true that the preparation of land for the *even absorption* and the *even infiltration* of sewage must necessarily be attended by some considerable acreage outlay. This admission, however, is limited to the superficial area, and does not extend to the actual results upon the pockets of the ratepayers. If the cost of cleansing the sewage of a town containing a certain population (say 30,000), by filtration through natural soil, be compared with the outlay necessary to effect the same object by wide irrigation, it will be found that in the former case it will be difficult to exceed a charge on the ratepayers of twopence in the pound, while in that of the latter it is difficult to limit the charge at all, for it will entirely depend upon the extent of the farm, the local demand for sewage produce, and the degree of stringency by which the cleansing of the sewage is enforced.

The experience gained since the execution of the works of Merthyr Tydfil and Kendal, which are so often referred to as example works, enables me already to state that the cost of preparing land for intermittent filtration can be considerably reduced when relieved of the disadvantages which invariably attend first efforts. In fact, I am now carrying out combined works of surface irrigation with intermittent filtration in stiff loams, gravelly lands, and peaty soils, and have a difficulty in determining under what precise circumstances the acreage cost of one process is greater than that of the other. In this observation I am assuming that the whole of the works essential to the perfection of each system are included in the comparison.

The laying out of surfaces for irrigation to swallow up sewage at the rate of 4,435 tons per acre, as at the Lodge Farm (which at ½d. per ton amounts to 9*l.* 4s. 9d.) is easy and cheap enough, but if the value of the sewage itself is to be recognised, the preparation of the land and the cost of preparing it are quite different matters and require considerable care.

The only real difficulty in either wide irrigation or intermittent downward filtration is experienced in cases where the population contributing the sewage is limited, and where the discharge of the sewage is very irregular,—at some period of the day the volume

being little or nothing, and at times considerable. In such cases it is difficult to deliver to the filtration area the precise quantity of sewage it is designed to absorb and purify, and the same thing, but in a less degree, occurs in surface irrigation, where the object should be to give to vegetation only that quantity of sewage which it can appropriate with advantage. But the trouble in both cases has now been overcome by the use of "the regulator" (see Appendix H.).

CII.—Combination of Intermittent Downward Filtration with Wide Surface Irrigation essential alike to the Profitable Utilisation of the Sewage and to the constant Purification of the Effluent. We now approach a branch of the sewage question to which I, as an old agriculturist, attach, perhaps, more importance than any other object connected with it. I refer to the judicious combination of intermittent filtration—as a certain means of purifying foul liquids—with surface irrigation as the only means of utilising sewage to the full extent to which it is susceptible. Such an arrangement is shown by Drawing XX., which exhibits the farm laid out on the combined principle at Abingdon, as well as the sewerage of the Borough.

Although the advantage of being able to resort to a process which, by itself, enables a sanitary authority on an average of years to cleanse for a permanency the liquid refuse of a thousand persons by its passage through an acre of land may be very great in the cases of towns situated in crowded districts, where land is only to be obtained at a very extravagant cost, it is even more satisfactory to know that by a combination of the two processes of intermittent filtration and wide irrigation, the loss now incident to sewage farming *may be turned into a profit*, and the heavy charge levied on the ratepayers of towns to make up that loss saved to them. This view of the case, however, can hardly be realised so long as sanitary authorities are led to believe that there is no very distinct difference between one process and the other; and that the sewage farmer can deal as readily with sewage when in excess as when he obtains only as much as he wants.

To remove this false impression it is necessary to be very explicit in describing how the combination should be effected. Intermittent filtration, instead of being "intensified irrigation" practised at the will of a tenant farmer, should be so designed and carried into execution as to form a separate work to be brought into use at those times when it would relieve the sanitary authority of any doubt as to the sewage being properly cleansed.

At present, all persons taking sewage from a sanitary author under the obligation of cleansing the whole that is delivered them and freeing it of its foul and noxious matters, are not o indisposed to pay for it, but in some form or other *require a c sideration for taking it.* The demand may be put in different wa but let it be what it may, it practically results in a loss to the ra payers,—whereas if the occupiers of the land laid out for surf irrigation were allowed, like the farmers in the neighbourhood the Heathcote Farm, near Leamington, or those near Cheltenham (s Section XCII.), to take only the quantity of sewage they wa and only when they want it, the case would assume a very differe shape. The sewage would then be regarded as a more valua article, and the users of it would be always willing to pay for it its true value. But to effect this arrangement it is desirable that t land prepared for intermittent filtration shall be properly and pe manently laid out in proper form, and that the prepared areas shou *remain in the hands of the sanitary authority,* in order that so mu of the sewage as is not sought and paid for may be cleansed i dependently of the farmers.

It is unnecessary to say anything more than was said in the la section as to the mode in which the areas to be devoted to inte mittent filtration should be formed. It is sufficient here to sta that wherever land can be obtained at a price low enough to justif its purchase and formation into a wide irrigation farm, the propor tion that may be favourably laid out for intermittent filtration as "safety valve," need not exceed one-tenth of the total area. Fo example, a sanitary authority of a town with a population of 30,00 which had purchased 300 acres for the utilisation of the sewage need only set aside an area of 30 acres for filtration to obtain th utmost value of the whole of the sewage;—270 acres would the be available for wide surface irrigation. To meet the wishes o the occupiers of the 270 acres, and at the same time to make th most advantageous terms for the ratepayers, the 30 acres set apar for filtration should be divided into three areas of 10 acres, each of which would come into use as the "safety valve" for a year i rotation. The sanitary authorities would then hold the one area i use, and let the remaining two areas on the best terms they could.

These terms, I need hardly say, cannot fail to be favourable, inas much as the full dosing of each area when in the hands of the sanitary authority would render them very productive for the two succeedin years, and the one area in use would still yield a produce sufficien when sold to pay the expenses of seeds, labour, &c.

TMENT & DISPOSAL OF SEWAGE.

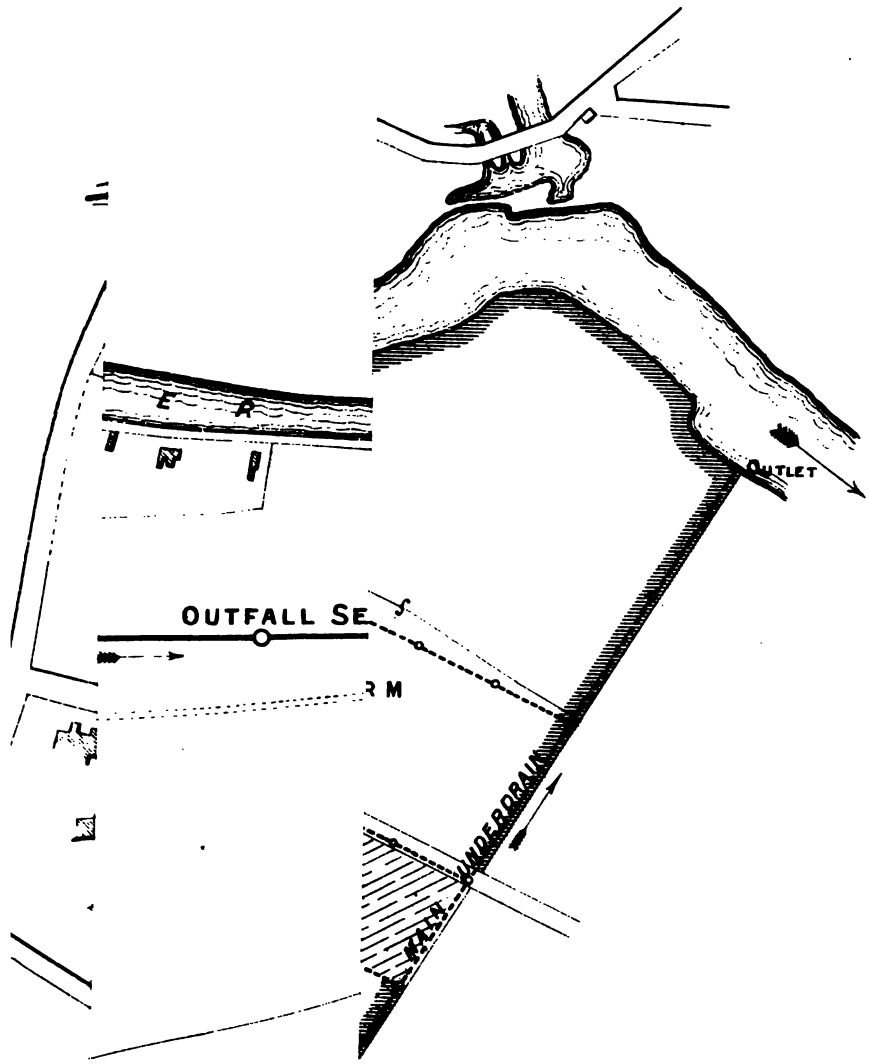
Drawing XI.

n of the

PTED AT ABINGDON,

VITH THE

IE CLEANSING OF THE SEWAGE.



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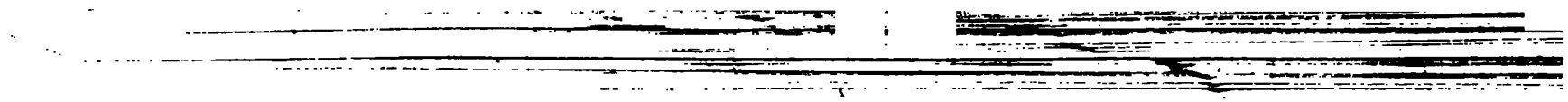


Hence it will be manifest that such an arrangement, securing as it would the perfect cleansing of the sewage independently of adverse seasons and adverse circumstances, and the disposal of the sewage at its full value, must result advantageously to all parties interested: to the sanitary authority and the ratepayers they represent, because they are conforming to the law by preventing river pollution and securing the best return from the sewage; to the occupier of the two remaining filtration areas, because the land will be enriched with the fertilising matter retained in the soil from previous dressings, and because they can have additional liquid sewage when wanted; and to the occupier or occupiers of the sewage farm (270 acres), because in like manner they can be masters of their own proceedings and receive sewage or not as they please. Unless, however, *that part of the arrangement depending upon the sanitary authority is scrupulously carried out*, the same waste of sewage and the same defilement of streams that is now inseparable from sewage farming, and the same disappointment that now prevails throughout the country in consequence thereof, will attend the proposed combination.

The necessity for the filtration area remaining in the hands of the sanitary authority, and of the strictest rules in relation to the treatment of sewage, has been forced upon my mind by observing that so long as the occupiers of sewaged land are *obliged* to cleanse the sewage on Sundays, and at night-time, or in wet seasons, and at times when the whole of their lands are in crop, they invariably resort to such expedients to "get rid" of it as are repugnant to both sanitary laws and agricultural economy.

[Upon this very important object the report of the Committee appointed by Mr. Sclater-Booth contains this extraordinary passage:

"*A Portion of a Sewage Farm should be deep-drained to act as a Land Filter.*

"A portion of each farm should be specially deep-drained and prepared for land filtering the sewage during winter or wet weather. When these filters are laid out in raised beds, some roots and vegetables can be cultivated with success as the sewage generally flows down the channels. But in times of flood and storms the sewage may rise above the beds so that it appears *oziers*, which would not be damaged by being flooded for days, may be the safest, and therefore the most

profitable crops to grow upon them. Experience has proved that each day's sewage may be disposed of throughout the year so as not to cause any nuisance. Land well drained, properly laid out and managed does not swamp at the surface, neither does it choke in the subsoil, as in fallow land oxidation goes on betwixt the intervals of irrigation, and at any time the few grains of matter extracted from the sewage waters are only a homœopathic dose to the land compared with the bulk of soil 6 feet in depth. It is a few grains of salt and organic matter extracted from the sewage which remain for the use of the plants, the water evaporating or flowing from the drains."

Though this is an acknowledgment, as far as it goes, of the advantage of *combining* filtration with wide irrigation, the terms in which it is expressed entirely fail to present the object in a tangible form, while the suggestion that sewage "may rise above the beds," and should therefore be applied to *osiers*, I am much afraid, will only mislead the sanitary student;—because in well-formed intermittent filtration areas no sewage can rise above the formation level unless they are formed in very low ground subject to floods, which is only exceptionally done, and because Osiers are of a family of plants particularly inimical to underdrainage, without which filtration cannot favourably exist.

I do not suppose that the Committee would suggest that osiers should be grown on land naturally dry and not requiring draining,—where in fact osiers never grow, or that they would suggest that sewage should be collected year after year on a surface which is seldom broken up, as is the case with osier-beds.

After the devotion of a great part of my life to the furtherance of agricultural improvements and sanitary progress, I sincerely regret that the report from which so much useful information was expected should be devoted to the simple reiteration of the conclusion that "town sewage can be best and most cheaply disposed of and purified by the process of land irrigation for agricultural purposes," without a single practical suggestion by which that great national object may be profitably attained.]

CIII. — COMBINED WORKS FOR THE INTERCEPTION AND DISPOSAL OF SEWAGE IN CROWDED VALLEYS FREQUENTLY ADVANTAGEOUS. RIVER

CONSERVANCIES FOR SANITARY PURPOSES. The remarks to be made in this section have been already in a great measure anticipated by what has been said with respect to the cleansing of trade-liquid refuse and the union of intermittent downward filtration with wide surface irrigation.

It is in those valleys in which manufacturing towns are congregated, and in those districts which form the suburbs of our large towns, that combination may be effected with the best advantage. One of the benefits to be gained by combination is the reduction in the number of sites required for the treatment of the sewage, and the lessening thereby of the chances of nuisance—real or imaginary—to the residents of the neighbourhood; and another is the reduction of the expenses of management which in most cases attends centralisation.

In the next section I shall show, by the best testimony I can offer, that although it has never yet been proposed to utilise or cleanse sewage by application to land without arousing considerable objection on the part of residents in the locality, the opposition is certainly not due to any ascertained injury, but rests entirely upon ideal or imaginary grounds.

Though, under the circumstances referred to, combination may have advantages over separate action, I have not unfrequently found upon going into figures of cost that the reverse is the case—that the annual charge upon the contributing ratepayers of districts is less when each authority adopts its own treatment than would be the case under combination, and that whatever the treatment of the collected sewage may be, it is quite possible to create too great an undertaking at one spot.

In this last remark I refer more particularly to the use of land by surface irrigation when it becomes very easy to over-do the market for sewage produce. I need hardly say that the same observation will apply to the manufacture of sewage manure intended for sale, for which there is generally a very limited demand, and that in the locality in which it is made.

The superior advantage of a combination of manufacturing towns consists in the fact that the waste liquors of different trades, when mixed with sewage, add so considerably to the quantity of the discharged liquid to be dealt with, that it is sometimes impossible—particularly in crowded valleys—to find sufficient land near at hand for the absorption and cleansing of the sewage of particular towns, while if the outflowing liquids from all the towns in one valley were placed under one conservancy, and dealt with by one comprehensive mode of collection—which would allow of the disposal

of the sewage wherever land could be best obtained—it would
possible to carry forward from one place to another, *i.e.*, from a high
to a lower level, that which could not be disposed of immediately
was discharged. In the valley of the Calder, for instance, in whi
there exists upwards of 5,000 mills and different works, and a pop
lation of nearly 500,000, there is ample land in the valley, as a whol
for the cleansing of the liquid refuse of every town and inhabite
district within it by some such plan as that suggested. The soil
this valley—as in many valleys in the manufacturing districts—
remarkably suitable for the cleansing of sewage and waste liquo
by filtration through small quantities of land, and if the suggeste
mode of treatment were adopted not only might the whole of th
sewage and waste liquids be cleansed without nuisance, but a r
covered source of water supply would be gained in the clarifie
effluent waters which would certainly be available for trade pu
poses.

CIV.—On the Sanitary Condition of Localities in Proximity t
Land to which Sewage is applied. It may afford the enginee
some data for meeting the objections which invariably arise to an
proposal to apply sewage to land, if the following facts and opinion
are placed before him.

The Rivers Pollution Commissioners give the following particular
in their first report. They say:

"We do not recommend irrigation for the abatement of the tow
sewage nuisance without having made ample inquiry into any risk
to health which may be incurred by the establishment of sewage
meadows in the neighbourhood of towns. Such inquiries have been
made at Edinburgh, Croydon, Norwood, and Barking, where irri-
gation has been carried on long enough and, near Edinburgh at least,
in a sufficiently careless manner to have certainly developed what-
ever elements of mischief may be inherent in the practice. Nowhere
have we found instances of ill-health that are properly attributable
to malaria or other causes due to irrigation. At Edinburgh we
were informed by Dr. Littlejohn that, though as medical officer of
health to the city, he looked with prejudice and displeasure on the
existence of sewage meadows in its suburbs, he had not been able to
connect the ill-health of certain localities in Edinburgh with the
Craigentinny meadows as its cause. Professor Christison, too,
President of the Royal Society of Edinburgh, speaking of these
meadows, in an address at the meeting of the Association for the
Encouragement of Social Science at Edinburgh, in October, 1863,
said (vol. ii., *Minutes of Evidence*, part iv.):

"'I have recently been making careful inquiry respecting this famous and somewhat unsavoury institution; many years ago my own prejudices were all against the meadows; I have been compelled to surrender them. I am satisfied neither typhus nor enteric fever, nor dysentery, nor cholera, is to be encountered in or around them, whether in epidemic or non-epidemic seasons, more than in any other agricultural district of the neighbourhood. About twenty-five years ago it was stated that the cavalry soldiers at Piershill barracks, which are situated very near them, were unusually liable to the zymotic diseases caused or promoted by foul emanations, and also that meat could not be kept in the officers' larder on account of the absorption of foulness and quickly following decay. Either, however, there was some mistake committed through prepossession, or the meadows are now worked on a better system, but at all events I have the assurance of Mr. Lockwood, surgeon of the Scots Greys, that during their late occupation of Piershill barracks for two years, the messman of the regiment never observed the meat to be injured, nor did he himself observe among the men anything but remarkable freedom from diseases at large. I think it right, in reference to the late introduction of the Craigentinny system of irrigation into the vicinity of other large towns, that these precise facts should be known.'

"Dr. Christison writes, 4th February, 1870, 'I have nothing either to add to or subtract from the above quotation from my Social Science address in 1863.'

"Dr. Ligertwood, surgeon to the 8th Hussars, stationed at these barracks, in 1868, says: 'During the four months the regiment has been quartered at Piershill the men have been very healthy, and so have the women and children. Between the barracks and the sea there are upwards of 200 acres of land under irrigation from town sewage; these sewage fields do not apparently exercise any unfavourable influence on the health of the troops, or perhaps I should say, that my opinion is, that *in spite of these*, the health of the troops at Piershill is good, the site of the barracks being open and well exposed to the sea breeze counteracts any evil influences from proximity to such fields. These fields are certainly a source of nuisance to those living in barracks from the offensive emanations given off from the open ditches conveying the sewage, and also from injudicious flushing of the fields; the stench in barracks is sometimes quite sickening. All this might, however, be remedied by the sewage being conveyed to the fields in covered ditches or pipes, and outlets placed on the pipes in the fields at proper intervals for

irrigating. During the years 1865, '66, and '67, the 4th Hussars were quartered at Piershill; I was surgeon in charge; the health of the regiment was remarkably good; during a portion of this time the cholera was epidemic at Leith and Edinburgh (not severe), but not a case occurred at Piershill barracks.'

"In reference to Barking we may add that during 1866, when the cholera was prevalent in some parts of North London, the North London sewage was constantly poured over the irrigated fields of Lodge Farm, but no case of cholera happened at the farm or near it. The only serious illness that has happened on the farm since it has been in the hands of the Metropolis Sewage Company was a case of scarlet fever in a newly built cottage, which attacked a labourer's family immediately on their coming into residence. But it was satisfactorily proved that the infection had been received by the family before their arrival, and it did not afterwards spread.

"At Norwood Dr. Alfred Cresswell gave evidence before the former Rivers Pollution Commission (First Report, River Thames), tending rather to implicate the irrigation meadows there as the cause of malarious fever. The following, however, is an extract from a letter dated December 21, 1869, in which he states his subsequent experience: 'My evidence went to prove that the irrigation fields *as a marsh* produced malarious diseases, and in this case intermittent fever, amongst the children living in the vicinity. At this period the works were badly managed, and the fluid allowed to remain on the field too long. I have resided in the neighbourhood ever since, and have the largest practice in it, especially attending the families of those who work on the fields, who also belong to clubs which I attend. Many of my patients' houses are within 150 yards of the sewage fields. Among others, there is a large girls' school standing between the fields and those houses where this illness existed in 1865-6. In this school, in which there are more than thirty inmates, there has not been a single case of illness from preventible diseases; and my last quarter's account was 5s. 6d. I have been able in no case to trace any illness to these fields. As for effluvia I will not say there does not exist any, but it is so seldom perceptable that a house built within 200 or 300 yards would command the same rent as if half a mile off. My investigations and independent observations during the last three years have made me an advocate for this method of utilising sewage matter. And as an instance of how perfectly the watery portion is purified, I can state that the water flowing over these fields, and thence conducted to a neighbouring brook, is frequently drank by persons who are ignorant of its source. It is clear, pel-

lucid, and tasteless. I repeat, therefore, that after watching the working of these fields, my opinion is, that when this system of sewage irrigation is *well managed*, the health of the inhabitants in the immediate vicinity is in no way influenced by it. I may mention that ours is a deep clay soil, and that I have no experience of light or sandy soils.'

"And at Beddington, near Croydon, it has been sufficiently established, whatever may be the amount of occasional nuisance owing to foul ditches, or perhaps to the ponding of foul water in hollows on the land, that no attack of disease has been consequent upon the process of irrigation there.

"The evidence of Dr. Alfred Carpenter is conclusive on this point. The following is an extract from his paper on 'Some points in the physiological and medical aspect of sewage irrigation,' read before the Social Science meeting at Bristol, October 2, 1869:

"'The visitor to Beddington will see a number of villas, which have been occupied for some years, with irrigated fields both in front and rear, whilst not a trace of enthetic disease has appeared in any of them, though I think the Beddington farm is capable of much improvement. At Norwood the population is much greater and much nearer to the fields, probably 400 persons living within 200 or 300 yards from the farm. Previously to its establishment in that district fever abounded; since then that disease has all but disappeared, and the mortality of the district has steadily declined. The death-rate for Norwood, population about 5000, for the last six years, according to Dr. Westall's mortality tables, is as follows, viz:

1863	18·76	
1864	18·89	
1865	18·17	Sewage farm established.
1866	15·34	
1867	14·21	
1868	12·07	

"'I do not mean to assert that the low mortality in Norwood is due to the establishment of the sewage farm, neither do I expect that low rate to be maintained; but I contend that if miasms were produced by sewage farms, then the mortality would have increased after the establishment, and that preventable diseases would have more abounded than before the event. We find the contrary to be the fact. From the above table it will be seen that the establishment of the sewage farm in 1865 was immediately followed by a decrease in mortality, which would not have been the case if miasms had been promoted by their formation. Then, again, the Beddington farm of

nearly 300 acres is within 500 yards of a populous portion of our town, and within 900 yards of the centre of the place; it lies to the westward of the town, and yet I can safely say that a continuance of west wind is always accompanied by a diminished amount of ordinary sickness in the place, and our ordinary mortality is generally below 20 per 1000. At Norwood, moreover, a public footpath passes through the fields, which is frequented by hundreds of persons for recreation and amusement, especially on a Sunday. The persons so using the footpath have been frequently surprised when they have been told that their walks for pleasure have been taken through the sewage farm of the Croydon Local Board of Health. The path is much more frequented than other footpaths in the neighbourhood, which would not be the case if the fields were the nuisance they are supposed to be.' "

In the Fourth Report of the Rivers Pollution Commission further evidence is given upon this subject by Dr. Littlejohn, the medical officer of health to the City of Edinburgh. After bearing testimony to the health of the village of Restelrig, which is surrounded by these meadows, he says:

" I expected that the first part of Edinburgh (Regent-terrace and Carlton-terrace on the Calton Hill), against which the wind blowing over these meadows impinges, would have exhibited evidence of infection in the shape of cholera or typhoid fever, but I have totally failed to find it so." In reply to further questions, he says of the neighbouring barracks which the Commissioners state are being continually filled with fresh men who arrive of course unaccustomed to the circumstances in which they are placed: " No injurious effect is produced by the meadows which is perceptible in the state of their health. We have also to add to this list a collection of children of the poorest class, who have been kept under the auspices of Dr. Guthrie, at Marionville, which is the very centre of the meadows. Thus the men in the barracks (on the one side), the old people in Restalrig (midway), and the very young children with debilitated constitutions (on the other side), are healthy. With these three delicate tests, including Regent-terrace and Carlton-terrace, we have failed to show that the meadows are prejudicial to health, in fact, opposite evidence might be obtained of a very strong kind.'

As to the liability to certain diseases, which some of the opponents of irrigation and intermittent filtration state attends the consumption of vegetables produced from sewage, or from the flesh of animals which have been fed upon sewage-grown produce, we have the following facts and opinions.

In a letter to me, dated July of last year, Mr. Dyke, the medical officer of health for the urban and rural sanitary authorities of Merthyr Tydfil, says: "The vegetables produced on the areas are consumed by the public resident in Merthyr, and no evil results have followed. Diarrhœa is a disease which would result from the use of bad vegetables. The Registrar-General drew especial attention to the fact that the mortality due to diarrhœa was less in Merthyr than in any town in the kingdom."

In 1871, the Sewage Committee of the British Association invited Dr. Spencer Cobbold to make an examination of the carcass of an ox, which had been fed for nearly two years on sewage-grown produce at Bretons Farm, to ascertain the presence or absence of entozoa. The examination was made in the presence of Professors Marshall and Corfield, as well as other members of the Committee, and the result is given in the following report of Dr. Cobbold:

"Your Committee having invited me to examine the carcass of an ox fed for two years past on sewage-grown grass at Mr. Hope's farm near Romford, I have to report the perfect freedom of that animal from internal parasites of any kind.

"I attribute this marked negative result to the following circumstances:—First, the animal did not graze on the farm, but was fed exclusively upon vegetable products cut and carried from the land. Secondly, the porous nature of the soil and subsoil alike would rapidly carry off the sewage, and thus insure the passage of parasitic germs into the soil itself. Thirdly, I noticed on the irrigated portions of the farm a remarkable absence of those molluscan and insect forms of life which frequently play the part of intermediary bearers. Fourthly, the only mollusks I detected were examples of *Lymneus pereger;* these were obtained from a small pit of water to which the sewage had no access, and when examined after death were not found to contain any cercarian larvæ. Fifthly, the flaky vegetable tufts collected by me from the sides of the furrows occupied by sewage-currents consisted chiefly of *Batrachospermum moniliforme*, in the filaments of which were numerous active free nematodes, but no ova of any true entozoon. Sixthly, the sewage had a strong smell of beer, suggesting the presence of sufficient alcohol to destroy the vitality of ordinary parasitic germs, though it was abundantly manifest that the free nematodes had suffered nothing in consequence.

"As some guarantee for the efficient manner in which the carcass of the ox was examined, I may mention that the superficial muscles, with their associated areolar and aponeurotic coverings, were particularly investigated, portions of certain muscles, such as the scaleni and sterno-maxillaris, being dissected through and through.

All the viscera were likewise scrutinised, especially the brain, lungs, liver, bladder, kidneys, paunch, reed, cæcum, and other natural divisions of the intestinal canal. The animal was not excessively fat, whilst its muscles were well developed and of a deep carneous lustre."

Upon this report the Sewage Committee remark:

"With regard to the examination of the carcass of the ox, which had been fed for twenty-two months on sewaged produce at Bretons Farm, those members of the Committee who were present and examined it with Dr. Cobbold concur in his statement as to its perfect *freedom from internal parasites of all kinds;* and they can also subscribe to most of his observations with regard to the possible reasons for this immunity. They wish especially to draw attention (1) to the fact, that on this farm there is 'a remarkable absence of those molluscan and insect forms of life which frequently play the part of intermediary bearers' to entozoal larvæ; it would appear that the sewage drives these creatures away or kills them; and (2) to the composition of the 'flaky vegetable tufts' collected from the sides of the carriers; these contained numerous active free nematodes, but no ova of any true entozoon.'

"But the Committee cannot support the opinion expressed by Dr. Cobbold, that the strong smell of beer which the sewage had (caused of course merely by hop waste) would suggest 'the presence of sufficient alcohol to destroy the vitality of ordinary parasitic germs,' as the quantity of alcohol which would be necessary for this purpose in so large a bulk of sewage would be enormous, and especially as, as Dr. Cobbold says, 'it was abundantly manifest that the free nematodes had suffered nothing in consequence.'

"It appears, then, that, as far as this one case goes (and it is certainly as conclusive as a single case could possibly be), there is no evidence that entozoal forms of life are to be found on the farm at all in any stage of their existence, or in the flesh of an animal fed exclusively for twenty-two months on sewage produce grown on the farm."

Evidence of the health of cows fed upon sewage-produced grass is given in the Fourth Report of the Rivers Pollution Commissioners. Dr. Littlejohn, in his evidence before the Commission, says:

"The cows in Edinburgh are chiefly fed with grass that is grown on the Craigentinny meadows. I have thought that there might be objection to feeding cows upon grass so grown, because I was of opinion that such grass might be of inferior quality; but practically I have failed to detect any bad effects resulting from the use of such grass. Entozoic disease is remarkably rare in Edinburgh. Tape-

worm is hardly ever heard of, except in the cases of persons coming from other places to reside here. All the cattle which have been fed upon the sewage-grown grass find their way to our slaughter-houses, where they are examined by inspectors and myself. We do not find any of those diseased appearances which are met with in what is called 'diseased' meat more frequently in cows which have been fed upon sewage grass than in cows which have been fed upon other kinds of food. Like all animals in towns, we find that they are more liable to suffer from contagious diseases, such as pluero-pneumonia. But that is decidedly not attributable to any peculiarity in their food. So far as my observations have gone, the use of sewage grass for the food of animals is unobjectionable. We are annoyed occasionally by attacks of diphtheria which occur in various parts of the town, and I have had to inquire as to the milk supplied to families who have been affected, but I have failed to trace connection between the use of particular kinds of food and any special attack of diphtheria, or, in fact, any other disease. Trichiniasis is not known in Edinburgh. The practice of keeping cows in Edinburgh has prevailed from time immemorial. If there had been anything in the idea that sewage grass would lead indirectly to entozoic disease, it has had plenty of time to develop itself, and Edinburgh is not only the seat of a great medical school, but medical observation is carried to the highest point in Edinburgh, so that it could not fail of being detected."

CV.—Concluding Remarks on the Treatment and Disposal of the Sewage, and the Means to be provided to preserve Rivers and Running Streams from Pollution. The following conclusions form an epitome by which I think it right to close the last division of my lectures.

I. That the liquid refuse of towns, villages, hamlets, institutions, and dwellings, can only be continuously, effectually, and economically cleansed and rendered legally admissible into inland rivers by application to land.

II. That where agricultural land can be obtained for the purpose at a cost not exceeding fifty per cent. above its ordinary saleable value, resulting in a rent-charge not exceeding 50s. an acre, the sewage should be applied to it on the principle of surface irrigation on a wide scale, combined with intermittent filtration through a small proportion of the area purchased.

III. That where land can be obtained at any price the repayment of which with interest will amount to a charge above 50s. but not exceeding 7*l.* per acre, a sanitary authority is justified in applying the

sewage of their district to a medium extent of land prepared for irrigation combined with intermittent filtration, and if the extent does not exceed that which will satisfy the demands of local markets for vegetables and grass produced from it an immediate return may be expected sufficient to pay all outgoings, including the renting charge.

IV. That where land can only be obtained at a price involving an annual charge of 10*l.* an acre and more, a sanitary authority is only justified in acquiring just sufficient land to secure a permanent cleansing of the sewage which may be limited to one acre for every thousand of the population, always assuming that the land is quite suitable, that it is naturally or artificially underdrained to the full depth of six feet, and properly prepared to receive the sewage, and that the sewage is applied quantitatively and intermittently.

V. That in the case of towns on tidal rivers, and on the seaboard, sanitary authorities will in many cases be justified in resorting to chemical precipitation, supplemented by filtration through natural soil, or through artificial beds, to clarify the sewage before ultimate discharge. It is only in cases where sewage cannot return to the shore that it should be discharged direct into the sea.

VI. Allotment gardens for the labouring poor form the most appropriate ground for the utilising of the liquid sewage of villages, *if well arranged and managed.*

VII. In applying sewage to land for irrigation, the wider the area beyond the quantity that will meet the demands of local markets for sewage produce, the greater will be the loss upon the present ratepayers.

VIII. Sewage farming can never be remunerative to the sanitary authority who lets, nor to the farmer who hires the sewaged land, so long as the latter is compelled to take and cleanse the sewage at all times and under all conditions. It is therefore essential that a properly prepared plot of land for intermittent filtration should be held by the local authority, to receive the sewage when not wanted by the farmer.

IX. In order to satisfy the just demands of manufacturers for the admission of trade liquid-refuse into the common sewers of a town, the provision of land for the intermittent filtration of the sewage and trade liquors to be discharged should be held particularly in view, whether towns are treated separately, or in combination under a Conservancy Board.

X. The practice of loading land laid out for irrigation with excessive quantities of sewage should be strictly avoided, as one subversive of the law in respect to river pollution, and opposed to economical results from sewage utilisation; this point will be gained by the pro-

vision of a properly prepared plot of land for the intermittent filtration of the sewage which is in excess of the quantity actually required.

XI. Land receiving sewage should be most carefully prepared to distribute it while in a fresh condition. All half and half measures result sooner or later in river pollution, and loss to the ratepayers.

XII. The most scrupulous care should be taken when discharging sewage into both inland and tidal rivers to prevent the silting up of navigable channels by road detritus and other solid matters.

Having thus recorded my own conclusions on the disposal of the sewage of towns and villages, and referred to those of the recent Committee appointed by the President of the Local Government Board, I will add the conclusions arrived at by the Select Committee on the Sewage of Towns in the year 1862.

Conclusions of Select Committee on the Sewage of Towns.

"1. The evidence proves that sewage contains the elements of every crop which is grown.

"2. That as compared with solid manure there are advantages in the application of sewage manure to land.

"3. The evidence proves that town sewage contains a large amount of heat, which in itself is beneficial in stimulating vegetation.

"4. The evidence also proves that the water alone of sewage is of great benefit for agricultural purposes.

"5. The evidence further proves that one ton (224 gallons) of average town sewage contains an amount of manure which, if extracted and dried, would be worth a little over 2d., taking Peruvian guano (at 11*l.* per ton) as the standard.

"6. A judicious use of town sewage permanently improves land.

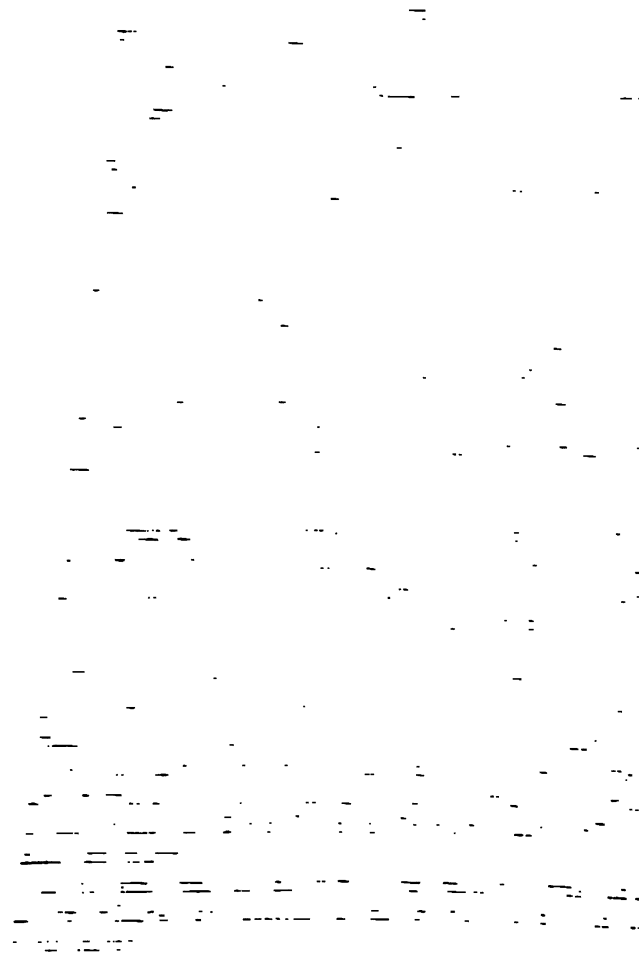
"7. Sewage may be applied to common grass, Italian rye-grass, and also to roots and grain crops, with great advantage, dressings with sewage hastening vegetation.

"8. Sewage-grown grass has a great effect in increasing the quantity and richness of the milk of cows, as well as improving the condition of the cattle, which prefer sewaged grass to all others.

"9. The earth possesses the power of absorbing from sewage all the manure which it contains, if the dressings in volume are proportioned to the depth and quality of the soil.

"10. Those who use sewage should have full control over it, that they may apply it when and in what quantities they may require it.

"11. Heavy dressings of sewage (8,000 to 9,000 tons per acre) are wasteful; less dressings (500 to 2,000 tons per acre) when more carefully applied, produce better results. The enormous dressings recommended by some witnesses would be agriculturally useless, as the sewage would flow over and off the surface unchanged.



sanitation, I do not wish to overlook the labours of the late Dr. Parkes and of Dr. Angus Smith, of Mr. Simon and Dr. Farr, of Dr. Buchanan and Mr. Netten Radcliffe, and of Dr. Acland and Dr. de Chaumont, as well as those of less prominent members of the medical profession, who have not only brought home to engineers the fact that there is for them a very wide field of action, but have made every reading man know that many diseases may be prevented and life prolonged by pure air and pure water, which shall be within the reach of all alike. When mentioning the names of the more forward men in the medical profession, I cannot omit that of Mr. Robert Rawlinson, C.B., C.E., who has done much for which his brother engineers may be grateful. I am glad of this opportunity of making this last acknowledgment, for although I have felt it my duty, owing to the influential position occupied by Mr. Rawlinson, to state in distinct terms the opinions I hold on several practical points in opposition to those he has officially expressed, and have been sorry to observe in the last report proceeding from his pen a desire to uphold the opinions he formed twenty years back without regard to the more recent experiences of other persons as earnest and as worthy of consideration as himself, I am not the less disposed to express my appreciation of his valuable public services.

To the teachings of the eminent persons I have mentioned I would direct the studies of all young sanitary engineers. Unfortunately, however, it is within the power of political and social influences, when brought to bear upon the Government of the day, to set aside the best labours of individuals, however soundly based and wisely directed. This is to be regretted, because the student is not always able to discover the reason why the best counsels are not adopted by the nation. That my meaning may be understood, I would especially point to the remarkably valuable chemical work performed by Dr. Edward Frankland as a Rivers Pollution Commissioner. His reports are singularly instructive. He is acknowledged throughout Europe to have done more than any chemist of the present day to advance sanitation. Yet two successive Governments have put aside, *i.e.*, they have not adopted, his recommendations, though endorsed by many of the leading chemists of other countries besides his own.

I will give here a Table which will be found very useful by the engineer. It will enable him to ascertain at once the annual charge which will be made upon a district to repay with interest the amount which it may be necessary to expend on sanitary works, if a local authority should borrow the money from the Public Works Loan Commission.

TABLE showing the equal Annual Amount of Principal combine
the under-mentioned Rates of Interes

No. of Years in which Loans to be repaid.	3 Per Cent. per Annum.						3½ Per Cent. per Annum.						4 Per Cent. per Annum.					
	Average Annual Instalment of Principal and Interest.						Average Annual Instalment of Principal and Interest.						Average Annual Instalment of Principal and Interest.					
	£1			£100			£1			£100			£1			£100		
		s.	d.	£	s.	d.		s.	d.	£	s.	d.		s.	d.	£	s.	d.
1	1·0300	=20	7½	103	0	0	1·0350	=20	8⅝	103	10	0	1·0400	=20	9½	104	0	0
2	·5226	10	5⅜	52	5	2⅝	·5264	10	6½	52	12	9½	·5301	10	7½	53	0	4½
3	·3535	7	0⅝	35	7	0⅝	·3569	7	1⅝	35	13	10⅓	·3603	7	2½	36	0	8½
4	·2690	5	4⅝	26	18	0⅝	·2722	5	5¼	27	4	6	·2754	5	6	27	10	11½
5	·2183	4	4⅜	21	16	8⅝	·2214	4	5¼	22	2	11⅓	·2246	4	6	22	9	3
6	·1845	3	8¼	18	9	2½	·1876	3	9	18	15	4	·1907	3	9⅝	19	1	6½
7	·1605	3	2⅝	16	1	0¼	·1635	3	3¼	16	7	1	·1666	3	4	16	13	2½
8	·1424	2	10¼	14	4	11	·1454	2	11	14	10	11¼	·1485	2	11⅝	14	17	6
9	·1284	2	6⅝	12	16	10½	·1314	2	7½	13	2	10⅝	·1344	2	8¼	13	8	11½
10	·1172	2	4¼	11	14	5½	·1202	2	4⅝	12	0	5⅝	·1239	2	5¼	12	6	7
11	·1080	2	2	10	16	1⅝	·1110	2	2⅝	11	2	2¼	·1141	2	3¼	11	8	3½
12	·1004	2	0	10	0	11	·1034	2	0⅝	10	6	11⅛	·1065	2	1⅝	10	13	1½
13	·0940	1	10½	9	8	0⅜	·0970	1	11¼	9	14	1⅛	·1001	2	0	10	0	3½
14	·0885	1	9¼	8	17	0½	·0915	1	10	9	3	1⅜	·0946	1	10⅜	9	9	4
15	·0837	1	8	8	7	6½	·0868	1	8⅜	8	13	7⅜	·0899	1	9¼	8	19	10½
16	·0796	1	7½	7	19	2⅜	·0826	1	7⅜	8	5	4⅛	·0858	1	8⅛	8	11	7½
17	·0759	1	6½	7	11	10¾	·0790	1	7¼	7	18	1	·0821	1	7⅜	8	4	4½
18	·0727	1	5⅝	7	5	5	·0758	1	6¼	7	11	7⅛	·0789	1	7	7	17	11½
19	·0698	1	4⅝	6	19	7½	·0729	1	5⅝	7	5	10½	·0761	1	6½	7	12	3½
20	·0672	1	4⅛	6	14	5¼	·0703	1	5	7	0	8⅝	·0735	1	5⅝	7	7	2
21	·0648	1	3⅝	6	9	9	·0680	1	4½	6	16	1	·0712	1	5	7	2	6½
22	·0627	1	3	6	5	6	·0659	1	3⅞	6	11	10½	·0691	1	4⅛	6	18	4½
23	·0608	1	2½	6	1	7½	·0640	1	3⅜	6	8	0½	·0673	1	4¼	6	14	7½
24	·0590	1	2⅛	5	18	1⅞	·0622	1	3	6	4	6½	·0655	1	3⅞	6	11	2
25	·0574	1	1⅝	5	14	10¼	·0606	1	2¼	6	1	4¼	·0640	1	3¼	6	8	0½
26	·0559	1	1½	5	11	10½	·0592	1	2¼	5	18	5	·0625	1	3	6	5	1½
27	·0545	1	1	5	9	1½	·0578	1	2	5	15	8½	·0612	1	2⅝	6	2	5½
28	·0532	1	0⅝	5	6	7	·0566	1	1⅝	5	13	2⅝	·0600	1	2⅜	6	0	0½
29	·0521	1	0¼	5	4	2⅝	·0554	1	1¼	5	10	10⅜	·0588	1	2	5	17	7½
30	·0510	1	0¼	5	2	0⅜	·0543	1	1	5	8	9	·0578	1	1⅝	5	15	8
31	·0500	1	0	5	0	0	·0534	1	0⅝	5	6	9½	·0569	1	1⅜	5	13	9
32	·0490	0	11⅝	4	18	0	·0524	1	0⅜	5	4	9½	·0559	1	1¼	5	11	11
33	·0482	0	11⅜	4	16	4¾	·0516	1	0¼	5	3	2¼	·0551	1	1	5	10	3
34	·0473	0	11¼	4	14	7	·0508	1	0¼	5	1	7	·0543	1	1	5	8	8
35	·0465	0	11	4	13	0	·0500	1	0	5	0	0	·0536	1	0⅝	5	7	2
36	·0458	0	10⅝	4	11	7	·0493	0	11⅝	4	18	7	·0529	1	0⅜	5	5	8
37	·0451	0	10⅜	4	10	2¼	·0486	0	11⅜	4	17	2⅓	·0522	1	0¼	5	4	6
38	·0445	0	10⅜	4	9	0	·0480	0	11⅜	4	16	0	·0516	1	0¼	5	3	3
39	·0438	0	10¼	4	7	7	·0474	0	11¼	4	14	9⅓	·0511	1	0¼	5	2	2
40	·0433	0	10¼	4	6	7	·0469	0	11¼	4	13	9⅓	·0505	1	0	5	1	1
41	·0427	0	10	4	5	4⅔	·0463	0	11	4	12	7	·0500	1	0	5	0	1
42	·0422	0	10	4	4	4⅔	·0458	0	10⅞	4	11	7	·0495	0	11⅞	4	19	1
43	·0417	0	10	4	3	4⅔	·0454	0	10⅞	4	10	9⅓	·0491	0	11⅞	4	18	2
44	·0412	0	9⅞	4	2	4¾	·0449	0	10⅞	4	9	9⅓	·0487	0	11⅞	4	17	4
45	·0408	0	9⅞	4	1	7	·0445	0	10¾	4	9	0	·0483	0	11⅞	4	16	7
46	·0404	0	9½	4	0	9½	·0441	0	10¾	4	8	2⅓	·0479	0	11¾	4	15	9
47	·0400	0	9½	4	0	0	·0437	0	10¾	4	7	4⅔	·0475	0	11¾	4	15	1
48	·0396	0	9¼	3	19	2¼	·0434	0	10¾	4	6	9⅓	·0472	0	11¾	4	14	5
49	·0392	0	9¼	3	18	4½	·0430	0	10¾	4	6	0	·0469	0	11	4	13	9
50	·0389	0	9¼	3	17	9½	·0427	0	10	4	5	4¾	·0466	0	11	4	13	1

with Interest which is requisite for the Repayment of Loans, at in any period of from One to Fifty Years.

4½ Per Cent. per Annum.						5 Per Cent. per Annum.						6 Per Cent. per Annum.						No. of Years in which Loans to be repaid.
Average Annual Instalment of Principal and Interest.						Average Annual Instalment of Principal and Interest.						Average Annual Instalment of Principal and Interest.						
£1			£100			£1			£100			£1			£100			
	s.	d.	£	s.	d.		s.	d.	£	s.	d.		s.	d.	£	s.	d.	
1·0450=	20	10¾	104	10	0	1·0500=	21	0	105	10	0	1·0600=	21	2½	106	0	0	1
·5339	10	8¼	53	8	0	·5378	10	9	53	15	7¼	·5454	10	11	54	10	10½	2
·3637	7	3¼	36	7	6½	·3672	7	4½	36	14	5	·3741	7	5¾	37	8	2¾	3
·2787	5	7	27	17	5¾	·2820	5	7¾	28	4	0¼	·2885	5	9½	28	17	2¼	4
·2277	4	6¾	22	15	7	·2309	4	7½	23	1	11½	·2373	4	9	23	14	9½	5
·1938	3	10¼	19	7	9	·1970	3	11½	19	14	0¼	·2033	4	0¾	20	6	8¾	6
·1697	3	4¾	16	19	5	·1728	3	5½	17	5	7¾	·1791	3	7	17	18	3½	7
·1516	3	0½	15	3	2¾	·1547	3	1	15	9	5½	·1610	3	2¾	16	2	0¾	8
·1375	2	9	13	15	1¾	·1406	2	9¾	14	1	4½	·1470	2	11½	14	14	0½	9
·1263	2	6¼	12	12	9	·1295	2	7	12	19	0	·1358	2	8¾	13	11	9	10
·1172	2	4¼	11	14	6	·1203	2	5	12	0	9¼	·1267	2	6¼	12	13	7	11
·1096	2	2¼	10	19	4	·1128	2	3	11	5	7¾	·1192	2	4¾	11	18	6¾	12
·1032	2	0¼	10	6	6¼	·1064	2	1½	10	12	11	·1129	2	3	11	5	11	13
·0978	1	11½	9	15	7¾	·1010	2	0¼	10	2	0½	·1075	2	1¾	10	15	2	14
·0931	1	10¼	9	6	2¾	·0963	1	11¼	9	12	8¼	·1029	2	0¼	10	5	11¼	15
·0890	1	9¾	8	18	0¼	·0922	1	10¼	9	4	6¼	·0989	1	11¾	9	17	11	16
·0854	1	8¼	8	10	10	·0886	1	9¼	8	17	4½	·0954	1	11	9	10	10¾	17
·0822	1	7¾	8	4	5¾	·0855	1	8½	8	11	1	·0923	1	10¼	9	4	8¾	18
·0794	1	7	7	18	9¾	·0827	1	7¾	8	5	5¾	·0896	1	9½	8	19	3	19
·0768	1	6½	7	13	9	·0802	1	7¼	8	0	5¾	·0871	1	9	8	14	4½	20
·0746	1	6	7	9	2½	·0779	1	6¾	7	16	0	·0850	1	8½	8	10	0	21
·0725	1	5½	7	5	1	·0759	1	6¼	7	11	11¼	·0830	1	8	8	6	1	22
·0706	1	5	7	1	4¼	·0741	1	5¾	7	8	3½	·0812	1	7½	8	2	6¾	23
·0689	1	4½	6	17	11¾	·0724	1	5½	7	4	11¼	·0796	1	7½	7	19	4½	24
·0674	1	4¼	6	14	10½	·0709	1	5	7	1	11	·0782	1	6¾	7	16	5¼	25
·0660	1	4	6	12	0½	·0695	1	4¾	6	19	1½	·0769	1	6½	7	13	9¾	26
·0647	1	3½	6	9	5¾	·0682	1	4½	6	16	7	·0756	1	6¼	7	11	4¾	27
·0635	1	3¼	6	7	0½	·0671	1	4¼	6	14	3	·0745	1	6	7	9	2¼	28
·0624	1	3	6	4	10	·0660	1	4	6	12	1	·0735	1	5¾	7	7	2	29
·0613	1	2¾	6	2	9½	·0650	1	3¾	6	10	1¼	·0726	1	5½	7	5	3¼	30
·0605	1	2¼	6	0	11	·0641	1	3½	6	8	3	·0718	1	5¼	7	3	7¼	31
·0596	1	2	5	19	2	·0633	1	3¼	6	6	7	·0710	1	5	7	2	0	32
·0588	1	2	5	17	6	·0625	1	3	6	5	0	·0703	1	4¾	7	0	7	33
·0580	1	1¾	5	16	0	·0618	1	2¾	6	3	6	·0696	1	4½	6	19	2½	34
·0573	1	1¾	5	14	7	·0611	1	2½	6	2	2	·0690	1	4½	6	18	0	35
·0566	1	1½	5	13	3	·0604	1	2¼	6	0	11	·0684	1	4¼	6	16	9½	36
·0560	1	1½	5	12	0	·0598	1	2¼	5	19	8	·0679	1	4	6	15	9½	37
·0554	1	1¼	5	10	10	·0593	1	2	5	18	7	·0674	1	4	6	14	9½	38
·0549	1	1	5	9	8	·0588	1	1¾	5	17	7	·0669	1	3¾	6	13	9½	39
·0544	1	1	5	8	8	·0583	1	1¾	5	16	7	·0665	1	3¾	6	13	0	40
·0539	1	1	5	7	9	·0578	1	1¼	5	15	8	·0661	1	3¾	6	12	2¼	41
·0534	1	0¾	5	6	10	·0574	1	1¼	5	14	10	·0657	1	3½	6	11	4¾	42
·0530	1	0¾	5	6	0	·0570	1	1¼	5	14	0	·0653	1	3½	6	10	7¼	43
·0526	1	0¾	5	5	2	·0566	1	1¼	5	13	3	·0650	1	3½	6	10	0	44
·0523	1	0¾	5	4	5	·0563	1	1¼	5	12	7	·0647	1	3½	6	9	4¾	45
·0519	1	0¼	5	3	9	·0559	1	1¼	5	11	11	·0644	1	3½	6	8	9¾	46
·0515	1	0¼	5	3	1	·0556	1	1¼	5	11	3	·0641	1	3½	6	8	2¼	47
·0512	1	0¼	5	2	5	·0553	1	0	5	10	8	·0639	1	3¼	6	7	9¼	48
·0509	1	0	5	1	10	·0550	1	0	5	10	1	·0637	1	3	6	7	4¾	49
·0507	1	0	5	1	3	·0548	1	0	5	9	7	·0634	1	3	6	6	9½	50

Having derived much information and assistance from many engineers, medical officers, local surveyors, and others, connected with the subject of these lectures, I desire thus publicly to acknowledge the fact, and to thank them for the aid they have rendered me. As these pages have been taken through the press for "readers" instead of hearers in the midst of business engagements, and it is more than probable that errors will be discovered, I venture to express the hope that upon such being found to be the case, they will be pointed out, in order that corrections may be made in the event of a second edition being called for.

LIST OF APPENDICES.

A. Description of Dr. Angus Smith's "Minimetric" Method of estimating the Quantity of Carbonic Acid in Air.

B. Description of Professor Pettenkofer's Method of estimating the Amount of Carbonic Acid in Air.

C. Extract from the Report of Dr. Hofmann and Professor Blyth upon the Effect of Impure Water on Animal Economy.

D. Explanation of Dr. Frankland's Method of ascertaining the Quality of Water used for Domestic Purposes.

E. Rainfall at Redmires, near Sheffield. Table by Mr. Hawksley showing the Three Consecutive Months in each Year, from 1836 to 1868, in which the Maximum and Minimum of Rain fell.

F. Extract from the Report of the Borough and Water Engineer of Liverpool as to (1) the "Sympathy between the Existing Public Wells," in the New Red Sandstone and (2) the "Diminished Yield of Public Wells in the Past," and Diagram showing the Fall of Water in the Chalk under London.

G. Explanation of Dr. Clark's Process for Softening Water by Lime.

H. Description of the Self-acting Sewage Regulator, or Automatic Sewage Meter, and of Sewage Works at Eastwick, Surrey. (With Two Plates.)

I. Details of the Quantity of Excreta and Refuse Material collected by Mr. Alderman Taylor's System of Scavenging at Rochdale, and the Cost thereof, with other Particulars of a similar System adopted at Warrington, Birmingham, Nottingham, and Blackburn.

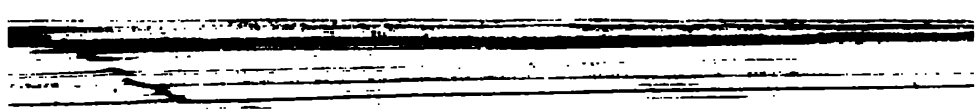
J. Rules and Regulations of the Norwich Water Works Company.

K. General Instructions of the Manchester Corporation as to Water Fittings.

L. Extract from the "Water Works Clauses Acts," 1847, 1863.

M. Regulations made under the Metropolis Water Act, 1871.

N. Mr. Bramwell's Description of Mr. Deacon's Waste Water Meter.



APPENDIX A.

ESTIMATION OF CARBONIC ACID BY MINIMETRIC ANALYSIS.

[*Extracted from "Air and Rain," by Dr. Angus Smith.*]

For definite amounts of carbonic acid.—"If we shake a bottle containing 644 cubic centims, or 23 ounces of common air, we obtain a precipitate such as that described above.* Now, if air containing twice as much carbonic acid were to be put into a bottle, the precipitate would be twice as great, but we could not ascertain its value by the eye. We cannot even make a probable approach to it. If, however, we use a bottle just half the size of the first, the air being still twice as bad as the first specimen, we should have a precipitate exactly the same, because, in fact, the amount of carbonic acid would be exactly the same. If the air were four times as bad we should then use a bottle four times smaller, and obtain a precipitate also exactly the same as the first; so on down to the smallest dimensions. I go here in the belief that, although we cannot approach at all closely when endeavouring to obtain the comparative value of two precipitates, we can retain in the memory with great exactness the character of one precipitate of a given density.

"If, then, we wish the air of a place to be kept at any one given state of purity, we should require only to have a bottle corresponding to the amount of carbonic acid and the trial could be made at once. This plan would not suffice for estimating the amount in any given air; it would estimate only one amount; but it would show clearly when there was more and when less.

* "Equal quantities of baryta water were poured into two bottles; air was blown into them from the lungs until a decided precipitate formed, equal in both cases. The amount of precipitate was estimated by testing the amount of baryta still in solution. When this was done several times by two persons the results were almost absolutely the same. Next day these same two performed the experiment, relying on the memory of the precipitate of the previous day; and the results were that what the oxalic acid required was 23·7 cubic centimes, 23·2, and 23·2. The difference in one case is ·0005 gramme of carbonic acid, as every cubic centime of the oxalic acid solution was equal to ·001 gramme of carbonic acid. This was repeated times without number, and served as a basis for a new mode of using the baryta and lime water tests. To this method of analysis I have given the name of *Minimetric*."

"When it was found so easy to remember a certain bulk of precipitate, it became important to know what bulk would be the most easily remembered. Must it be a minute quantity, such as a chemist would call a trace, or must it be a quantity such as we should call milky? Neither suffice.

"The first is too small for certainty; the second has no translucency, or so little that we cannot judge of the amount that lies behind. The quantity will be expressed most clearly by saying that the liquid is turbid and still translucent, but not so that you could read through it. Anyone may obtain it exactly by shaking a clear 23-ounce bottle, with half an ounce of baryta water in air containing ·04 per cent. carbonic acid, and this may easily and frequently be done to aid the memory.

"To be more precise, it is a precipitate obtained by throwing down baryta with ·2515 cubic centims of carbonic acid, or ·00224 gramme carbonate of baryta freshly precipitated in half-an-ounce of liquid.

"Some may prefer less; any amount will do if it is uniform.

"TABLE I.—To be used when the point of observation is the precipitate described. Half an ounce of baryta water containing about ·08 gramme baryta.

Air at 0° C, and 760 millims. bar.

Carbonic acid in the air per cent.	Volume of air in cubic centims.	Size of bottle in cubic centims.	Size of bottle in ounces, avoirdupois.	Carbonic acid in the air per cent.	Volume of air in cubic centims.	Size of bottle in cubic centims.	Size of bottle in ounces, avoirdupois.
·03	838	853	30·	·21	119	134	4·71
·04	629	644	23·	·22	114	129	4·54
·05	501	516	18·	·23	109	124	4·36
·06	419	434	16·	·24	104	119	4·19
·07	359	374	13·	·25	100	115	4·04
·08	314	329	12·	·26	96	111	3·90
·09	279	294	10·	·27	93	108	3·80
·10	251	266	9·	·28	90	105	3·70
·11	228	243	8·55	·29	87	102	5·59
·12	209	224	7·88	·30	84	99	3·48
·13	193	208	7·32	·40	63	78	2·74
·14	180	195	6·86	·50	50	65	2·28
·15	167	182	6·40	·60	42	57	2·00
·16	157	172	6·05	·70	36	51	1·79
·17	148	163	5·74	·80	31	46	1·61
·18	139	154	5·42*	·90	28	43	1·51
·19	132	147	5·17	1·00	25	40	1·40
·20	125	140	4·92	2·00	12	27	·95

"In Table I. all the information actually necessary is given, Column 2 is for fine measurements in cubic centimetres, indicating the amount of air which will contain the carbonic acid necessary for

* This size of bottle gives no precipitate in air with ·04 per cent. carbonic acid.

producing the precipitate of baryta when the proportion is according to any number in the first column. Column 3 is the same number, with the addition of 14·16 cubic centimetres, or half an ounce, which is the space occupied by the liquid. This, then, gives the size of the bottle to be used. Column 4 also gives the size of bottle to be used, the numbers being avoirdupois ounces fractions are not always given, and are not required so minutely as they are given.

"Perhaps in some cases it may be found more convenient to use those sizes of bottles which do not give any precipitate or milkiness when half an ounce of baryta water is shaken up with the air in them. The sizes corresponding to various percentages of carbonic acid are given in Table II.

"TABLE II.—To be used when the point of observation is 'no precipitate.' Half an ounce of baryta water, containing about ·08 gramme baryta.

Air at O° C, and 760 millims. bar.

Carbonic acid in the air per cent.	Volume of air in cubic centimes.	Size of bottle in cubic centimes.	Size of bottle in ounces, avoirdupois.	Carbonic acid in the air per cent.	Volume of air in cubic centimes.	Size of bottle in cubic centimes.	Size of bottle in ounces, avoirdupois.
·03	185	199	7·06	·15	37	51	1·81
·04	139	154	5·42	·20	28	42	1·48
·05	111	125	4·44	·25	22	36	1·29
·06	93	107	3·78	·30	19	33	1·16
·07	79	93	3·31	·40	14	28	1·04
·08	70	84	2·96	·50	11	25	·89
·09	62	76	2·69	·60	9	23	·83
·10	56	70	2·46	·70	8	22	·78
·11	51	65	2·29	·80	7	21	·75
·12	46	60	2·14	·90	6	20	·72
·13	43	57	2·01	1·00	5·5	19·7	·70
·14	40	54	1·90				

"In order to use this table, first in application to ordinary circumstances in life, we may assume that a bottle holding 5·42 ounces will not give any precipitate in the air around houses if we live in a tolerably fair atmosphere. To try the experiment the bottle must be very wide mouthed, so that we can put into it a rod covered with clean linen, and rub the sides dry and clean; we must then fill it with the air of the place, either by blowing in air with a bellows, or, better, drawing the air out with a pump, allowing that of the place to enter, or putting a glass or caoutchouc tube into the bottle and inhaling the air out of the bottle, so that fresh may enter. No way is more exact than this, if care is taken not to breathe into the bottle.

"This care is not at all difficult to take, and no amount of apparatus can be more accurate than this method, if done intelligently. If

the slightest amount of breath goes into the bottle the process of rubbing clean and drying must be undertaken anew.

"When the bottle is filled with the air of the place to be examined, add the half ounce of baryta water, put on the stopper and shake. If there is no precipitate the air is not worse than ·04 per cent. When it is desired to ascertain if it really contains as much as ·04, then a bottle holding 7·06 ounces must be used."

APPENDIX B.

PROFESSOR PETTENKOFER'S METHOD OF ESTIMATING THE AMOUNT OF CARBONIC ACID IN THE AIR.

This method is explained by Dr. Parkes, in his *Practical Hygiene*, in the following words:—

"A glass vessel is taken capable of holding from half a gallon to one and a half gallons. The capacity is determined by filling it with water, and by measuring the contents by means of a litre or pint measure (1 oz. = 1·733 cubic inches). The vessel is thoroughly dried and is then filled with the air to be examined, which is most readily done by pumping in the air with a bellows. When this is done 60 C.C. of clear lime or baryta water are put in, and the mouth is closed with an indiarubber cap. The vessel is agitated so that the lime water may run over the sides and then is left to stand for not less than six or eight hours and not more than 24 hours. The carbonic acid is absorbed by the lime or baryta water, and, consequently, the causticity of these fluids is, *pro tanto*, lessened. If the causticity of the lime or baryta is known before and after it has been placed in the vessel, the difference will give the amount of lime or baryta which has become united with carbonic acid.

"The causticity of lime is determined by means of a solution of crystallized oxalic acid. If 2·25 grammes of crystallized $\bar{O}\,(\bar{O}+3\,Aq)$ are dissolved in one litre of water, one C.C. will exactly neutralise one milligramme (·001 gramme) of lime; 30 C.C. of lime water are taken and exactly neutralised; good turmeric paper is the best plan for determining the exact point of neutralisation and the margin of the drop gives the most delicate indication. The amount of lime in the 30 C.C. is then equal to the number of C.C. of oxalic acid used; it is always somewhere between 34 and 39 milligrammes.

"After the lime has absorbed the carbonic acid of the air in the vessel, 30 C.C. of the solution are taken out and neutralised by oxalic acid; the difference between the first and second operations is doubled (to account for the 30 C.C. left in the vessel, 60 being always put in to allow 30 to be taken out, and also to allow a repetition of the experiment if necessary). This gives the amount of lime which

has combined with carbonic acid, and the amount of the latter is known by simply calculating according to the atomic weights and then converting weight into measure. This is done by multiplying by ·39521. The capacity of the vessel being known, the amount of CO_2 is calculated for 1000 volumes by simple rule of three. From the capacity 60 C.C. must be deducted to account for the lime water put in.

"A correction must be also made for temperature. The standard temperature being 62°, if the air of the room which is examined be below this, the quantity of air actually acted upon will necessarily be greater from condensation than would have been the case had the air been warmer; and conversely, if the temperature be higher than 62°, a less quantity of air must have been operated on than would have been the case had the air been at the lower temperature, viz., 62°. This error is corrected by multiplying ·0020361 (the co-efficient of expansion of air for 1° Fahr.) by the difference between 62° and the observed temperature, and then by the capacity of the vessel, and adding the product to the capacity if the temperature be below 62°, and subtracting it if it be above 62°.

"A correction for pressure is not necessary unless the place of observation be much removed from sea level; in that case the barometer must be observed and a rule of three stated.

$$\left.\begin{array}{l}\text{As standard height}\\ \text{of bar. (= 30 in.)}\end{array}\right\} : \left\{\begin{array}{l}\text{observed height}\\ \text{of bar.}\end{array}\right\} :: \text{capacity} : x.$$

"Baryta water may be used instead of lime water, but it must be free from traces of potash or soda."

APPENDIX C.

ON THE EFFECTS OF IMPURE WATER ON THE ANIMAL ECONOMY.

[*Extract from the Report of Dr. Hoffman and Professor Blyth, addressed to the General Board of Health in* 1856.]

"Very little is known of the nature of the ill-defined substances which constitute the organic matter generally found in water.

"Berzelius distinguishes two substances—crenic and apocrenic acids—which slightly differ in their chemical deportment; but these two bodies are as yet scarcely chemically examined, and much doubt still hangs over their individuality, and even over their existence. The organic matter in water has been divided into nitrogenous and non-nitrogenous matter; but all we know is that certain varieties of the organic matter found in water contain nitrogen, which is readily shown by treating them with hydrate of potash, when abundance of ammonia is evolved.

"The opinions of chemists are divided as to the manner in which organic matter in water is capable, under certain conditions, of producing a deleterious effect upon the animal economy. But it is now generally admitted that the substances which constitute the organic matter of water act injuriously, by no means in consequence of being poisonous themselves, but by undergoing those great processes of transformation called decay and putrefaction, to which all vegetable and animal matter is subject, when no longer under the control of vitality, either in plants or animals. These putrefactive processes either give rise to the formation of poisonous bodies, or they act simply as ferments, generating similar processes of decomposition in the substances composing the animal organism. Now, with special reference to the last mode of action, it is well established by general experience that nitrogenous substances are infinitely more liable to undergo putrefaction than organic bodies from which nitrogen is absent. And hence the very general and correct opinion that the deleterious character of organic matter in water is proportionate to the amount of nitrogen which it contains.

"Could this nitrogen be estimated with any degree of accuracy, such an estimate would certainly afford the most satisfactory element in the examination of the organic matter.

"Unfortunately, this estimate is attended with very considerable difficulties. The nitrogen of the organic matter, which has undergone putrefaction, and has therefore ceased to be deleterious, remains in the water—partly as ammonia, partly as nitric acid. It would, therefore, by no means be sufficient to evaporate the water, and to determine the amount of nitrogen in the residue. It would be absolutely necessary to estimate also the nitrogen present in the form of nitric acid, and of ammonia, and only after the deduction of their joint amount from the total amount, numbers would be obtained which, representing the quantity of still putrescible nitrogenous substances, would afford, within certain limits, the necessary data for a comparison of the organic matter present in different waters."

APPENDIX D.

EXPLANATION OF DR. FRANKLAND'S METHOD OF ASCERTAINING THE QUALITY OF WATER USED FOR DOMESTIC PURPOSES.

The following extract from "*Engineering*" is an account of Dr. Frankland's method of ascertaining the quality of water for domestic purposes:—

"Directing his attention chiefly to the amount and nature of the dissolved organic substance—to the consideration of which it has long been perceived that the question of wholesomeness is limited—he (Dr. Frankland) first ascertained, and proved, that the results obtained by methods then in use were either defective or erroneous, and in reality afforded only an increased facility for guessing whether water was wholesome or not. To meet his difficulty, Prof. Frankland devised a plan by which carbon and nitrogen, the two most important constituents of the organic substance in water, could be determined; and guided by the fact that so far as the nitrogenous animal substances introduced into water by sewage contamination might remain undecomposed, they were most likely to communicate unwholesome characters, he made those determinations the basis for judging as to the quality of the water. He also supplemented that plan by a determination of the nitrogen present in the water as nitrites, nitrates, and ammonia; for, since those are the products into which the nitrogenous animal substances in sewage are converted by the self-purifying action of the flowing water with which it is diluted in a river, their amount would indicate the extent to which the purification had advanced. By this means four results were obtained; in the first place, the total amount of combined nitrogen in the water would indicate to some extent the original sewage contamination, when the amount of combined nitrogen in sewage was taken into account. Of that total amount of nitrogen, the portion existing in undecomposed organic substance would be a measure of the sewage admixture which had not undergone conversion into products of a harmless nature, and it would serve to indicate the relative degrees of purity and wholesomeness of the water. If the amount of this organic nitrogen in water did not exceed $\frac{1}{50}$ of a grain per gallon,

corresponding to an unaltered sewage contamination of about ·5 p
cent., such a result might be disregarded as being little above t
average amount of experimental error, but in the event of larg
amounts of organic nitrogen being found, there would be go
reason for suspecting the quality of the water. A further indicati
of the degree of purity is furnished by ascertaining the amount
ammonia, which is a product of the putrefactive decomposition
the animal substance in sewage, and in water of good quality th
should not amount to more than about $\frac{1}{800}$ of a grain per gallo
The estimation of the nitrogen existing in the state of nitrites an
nitrates does not afford any direct indication as to the quality
water, but it is useful chiefly in revealing the probable history of th
water, and the extent to which the nitrogenous animal substances
the sewage or manure, with which it may have been previously con
taminated, have undergone conversion into those harmless products
At the same time, if the presence of a very large amount of nitroge
in this form indicates a considerable previous sewage or manur
contamination, amounting, say, to 5 per cent. or more, there is the
reason to suspect the quality of the water, since there would be
possibility that some of the deleterious contents of the sewag
admixture might still remain in the water and be capable of causing
mischief. If, at the same time, the water contained much organi
nitrogen, there would be ample reason for declaring it unfit fo
dietetic use. Apart from certain minutiæ in the shape of corrections
to allow for ammonia, nitrites and nitrates, originating from rai
water, these are the chief features of Dr. Frankland's method o
determining the quality of water, and it is, beyond question, th
only one yet devised that has been tested on any considerable scale,
and that has been found capable of indicating, with any claim to
scientific precision, the history and actual condition of water intended
for domestic use."

APPENDIX E.

RAINFALL AT REDMIRES (SHEFFIELD).

TABLE showing the three consecutive months in each year for 32 years in which the maximum and minimum of rain fell.

(Extracted from Minutes of Evidence given before Royal Commission on Water Supply.)

Year.	Minimum.		Maximum.		Total fall per year.
		inches.		inches.	inches.
1836	April May June	... 6·275	January February March	... 17·160	46·275
1837	March April May	... 4·815	October November December	... 12·580	38·625
1838	January February March	... 6·685	May June July	... 13·950	40·500
1839	March April May	... 5·600	July August September	... 20·905	49·255
1840	February March April	... 6·060	September October November	... 12·675	40·870
1841	February March April	... 6·120	May June July	... 14·555	46·340
1842	April May June	... 6·270	September October November	... 10·410	33·775
1843	July August September	... 7·730	April May June	... 15·370	43·645
1844	April May June	... 3·650	July August September	... 11·990	30·145
1845	February March April	... 7·010	August September October	... 14·200	45·350
1846	May June July	... 8·460	April May June	... 12·130	39·705
1847	January February March	... 6·815	October November December	... 13·225	39·605

Year.	Minimum.		Maximum.		Total fall per ye
		inches.		inches.	inches.
1848	March April May	... 8·840	August September October	... 17·010	48·175
1849	February March April	... 5·560	October November December	... 14·445	29·850
1850	March April May	... 7·515	July August September	... 11·405	39·280
1851	October November December	... 5·095	May June July	... 12·850	34·230
1852	March April May	... 3·265	September October November	... 17·015	45·900
1853	February March April	... 5·230	June July August	... 12·295	35·790
1854	March April May	... 5·000	October November December	... 14·925	34·800
1855	January February March	... 5·090	October November December	... 9·580	28·775
1856	January February March	... 7·220	August September October	... 17·120	43·155
1857	October November December	... 6·520	June July August	... 12·780	36·060
1858	January February March	... 3·710	August September October	... 12·260	34·810
1859	January February March	... 9·895	August September October	... 16·285	46·155
1860	February March April	... 8·140	August September October	... 13·740	44·280
1861	August September October	... 6·540	February March April	... 15·340	37·940
1862	January February March	... 8·845	March April May	... 12·620	40·060
1863	February March April	... 4·470	August September October	... 14·995	40·700
1864	June July August	... 5·710	September October November	... 11·325	31·880
1865	May June July	... 5·830	August September October	... 12·485	32·470

Year.	Minimum.		Maximum.		Total fall per year.
		inches.		inches.	inches.
1866	March April May	... 6·135	June July August	... 14·440	47·725
1867	October November December	... 7·710	February March April	... 13·705	38·850
1868	May June July	... 2·235			

APPENDIX F.

[*Extract from the Report of Mr. Deacon, C.E., Borough and Wa*
Engineer of Liverpool, July, 1875.]

"AS TO THE SYMPATHY BETWEEN THE EXISTING PUBLIC WELLS.

"1.—In September, 1866, an additional well having been sun
Bootle, the yield of that station was increased from 621,66
1,462,000 gallons per day, but in consequence of this increase
level of the water in Green Lane Well, 3½ miles distant, fell
feet, while the former rate of yield, viz., 2,956,000 gallons per
could not be quite maintained.

"2.—In October, 1870, Dudlow Lane Well was bored 142
deeper, and the yield was thereby increased from 771,500
1,415,000 in the following year, but in drawing this water the de
in the well fell two feet three inches below its former level, and
yield of Green Lane, two miles distant, was at the same ti
reduced from 3,741,000 (to which it had been raised by a new
and additional bore-hole sunk in 1868–9) to 3,580,000, the level of
water in the well being the same in both cases.

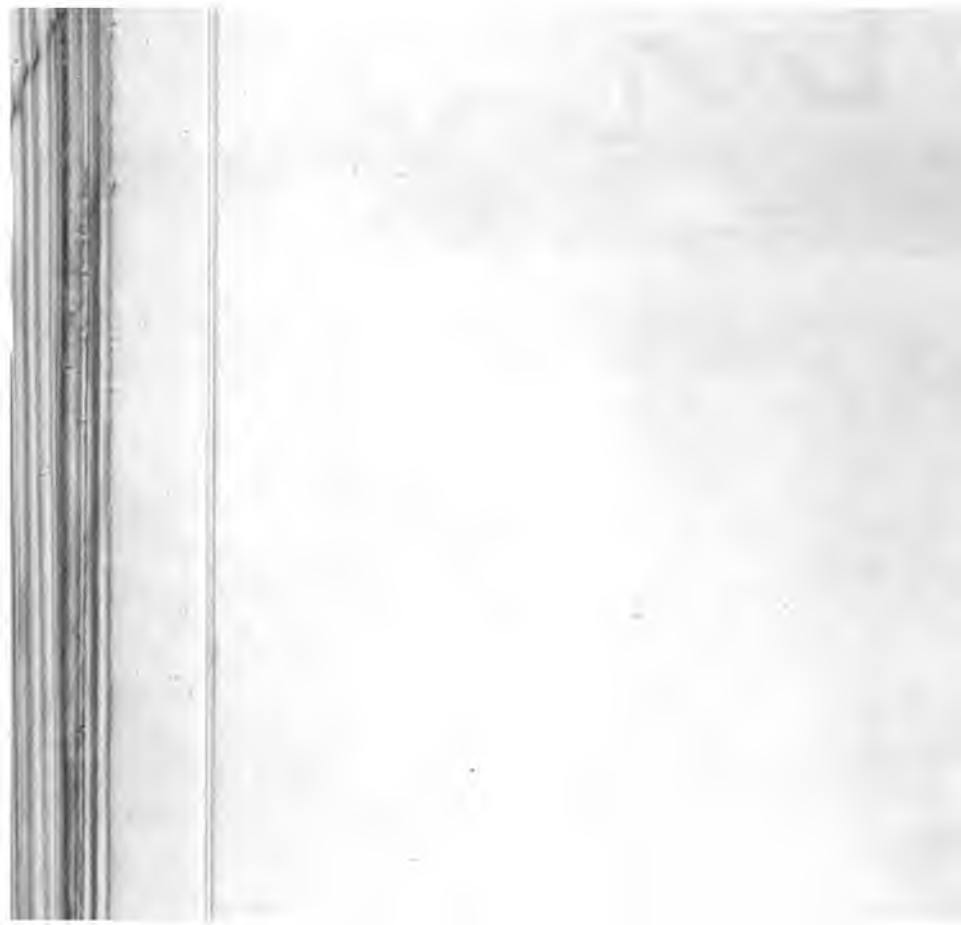
"3.—In February, 1872, on the recommendation of the Medi
Officer of Health, the pumping at Dudlow Lane ceased. The yi
being thus reduced from 1,415,000 to nil.

"After six months' time the yield from Green Lane h
increased from 3,580,000 to 3,667,000, the level of the water in
well being the same in each case.

"4.—In May, 1873, the pumping at Dudlow Lane was resum
but with the water standing in the well 31 feet 3 inches higher th
formerly, and the yield proved to be only 1,183,857.

"From the same level in Green Lane Well at whi
3,580,000 gallons were drawn prior to the stoppage of Dudl
Lane, and 3,667,000 during the stoppage, only 3,578,000 could
drawn at the beginning of 1875, when the pumping at Dudlow La
had been resumed for some time.

"Thus the water capable of being obtained at Green Lane w
less at the beginning of this year than in 1872, although t



Dudlow Lane water was pumped from a level 31 feet 3 inches higher than formerly, and a smaller yield obtained.

"This fact constitutes further evidence in support of the statement in the Engineer's Report of July, 1874, with reference to the diminishing yield of the wells, and indicates that influences beyond the increased pumping at other public wells are at work to produce a constant diminution of the yield of any well, when the water is maintained at a given level.

"AS TO THE DIMINISHING YIELD OF THE PUBLIC WELLS IN THE PAST.

"In his Report of July 16th, 1874, the Engineer pointed out a difficulty in estimating the actual rate of diminution of the yield of each well, arising from the fact that from time to time works had been executed in order to increase the supply, while bore-holes had sometimes been closed, and at other times opened, so that the yield of any well under precisely similar conditions could not in most cases be readily obtained.

"In compliance with the Water Committee's instructions, however, he made such an approximate determination of the rate of diminution as could be obtained by taking the difference between the respective yields in those few cases in which these conditions were at different periods similar, or nearly similar.

"The matter having now been referred to the Engineer for the particulars upon which his estimate was based, he submits the following examples of the method adopted :—

——	Gallons per day.	Height of water in well.	Per centage of decrease per ann.	Remarks.
In 1865, 2nd quarter, Windsor yielded	977,695	5′ 8″	·77	
„ 1874 „ „ „	909,906	3′ 11″		
„ 1869, November, Green Lane „	3,740,876	6′ 2″	2·0	
„ 1872, June, „ „	3,579,820	6′ 2″		
„ 1869, 4th quarter, Bootle „	1,570,077	8′ 10″	2·3	
„ 1874, 2nd „ „ „	1,407,616	7′ 3″		
„ 1871, 3rd qr., Dudlow Lane „	1,350,371	11′ 10″	2·9	An allowance for the discrepancy in the heights of water is made in the subsequent calculations.
„ 1874, 2nd „ „ „	1,240,440	46′ 9″		

"These cases give an average rate of diminution of 2 per cent. per annum.

"MUNICIPAL OFFICES,
"*July 10th*, 1875."

APPENDIX G.

THE SOFTENING OF WATER BY LIME.

[*Extracted from the Sixth Report of the Rivers Pollution Commissioners.*]

"The economy which carbonate of soda exhibits in comparison with soap, as a softening agent, is far surpassed by the gain which results from the use of lime for this purpose. The latter material costs only about 8d. per cwt., and this weight of lime will do the work of 20¼ cwts. of soap in softening hard water. To soften a quantity of hard water which requires one cwt. of lime the following would be the weight and cost of the three alternative materials :—

	£	s.	d.
1 cwt. quicklime	0	0	8
4¾ cwts. carbonate of soda	2	17	9
20¼ cwts. soap	47	1	8

"There is thus an enormous economy in the use of lime, and in the discovery of this process the late Dr. Clark, Professor of Chemistry in the University of Aberdeen, conferred a valuable boon upon the inhabitants of many hard-water districts. Dr. Clark's patent right has expired, and the public are therefore free to use this cheap and simple method of rendering hard water suitable for washing and cleansing purposes. The process is, however, only applicable to water which owes its hardness, entirely or chiefly, to the carbonates of lime and magnesia (*temporary hardness*). Water which is hardened by sulphate of lime or sulphate of magnesia (*permanent hardness*), cannot be thus softened, but any water which softens by boiling for half an hour will be softened to an equal extent by this method. The hard water derived from chalk, limestone, or oolite districts is generally well adapted for it.

"The following is Dr. Clark's own account of the process (*Journal of the Society of Arts*, 16th May, 1856) :—

"'In order to explain how the invention operates, it will be necessary to glance at the chemical composition and some of the chemical properties of chalk; for, while chalk makes up the great bulk of the matter to be separated, chalk also contains the ingredient that

brings about the separation. The invention is a chemical one for expelling chalk by chalk. Chalk, then, consists, for every one pound of 16 ounces, of lime nine ounces, carbonic acid seven ounces.

"'The nine ounces of lime may be obtained apart by burning the chalk, as in a lime-kiln. The nine ounces of burnt lime may be dissolved in any quantity of water not less than 40 gallons. The solution would be called lime-water. During the burning of the chalk to convert it into lime the seven ounces of carbonic acid are driven off. This acid, when uncombined, is naturally volatile and mild; it is the same substance that forms what has been called soda-water, when dissolved in water under pressure.

"'Now, so very sparingly soluble in water is chalk by itself, that probably upwards of 5,000 gallons would be necessary to dissolve one pound of 16 ounces, but by combining one pound of chalk in water with seven ounces additional of carbonic acid, that is to say, as much more carbonic acid as the chalk itself contains, the chalk becomes readily soluble in water, and, when so dissolved, is called bicarbonate of lime. If the quantity of water containing the one pound of chalk with seven ounces additional of carbonic acid were 400 gallons, the solution would be a water of the same hardness as well water from the chalk strata, and not sensibly different in other respects.

"'Thus it appears that one pound of chalk, scarcely soluble at all in water, may be rendered soluble in it by either of two distinct chemical changes, soluble by being deprived entirely of its carbonic acid, when it was capable of changing water into lime water, and soluble by combining with a second dose of carbonic acid, making up bicarbonate of lime.

"'Now, if a solution of the nine ounces of burnt lime, forming lime-water, and another solution of the one pound of chalk and the seven ounces of carbonic acid, forming bicarbonate of lime, be mixed together, they will so act upon each other as to restore the two pounds of chalk, which will, after the mixture, subside, leaving a bright water above. This water will be free from bicarbonate of lime, free from burnt lime, and free from chalk, except a very little, which we keep out of account at present for the sake of simplicity in this explanation. The following table will show what occurs when this mutual action takes place:—

Agents.			Products.	
Bicarbonate of lime in 400 gallons	Chalk	16 oz.	= 16 oz. of chalk	= 2 lbs.
	with			
	Carbonic acid	7 oz.	= 16 oz. of chalk	
Burnt lime in 40 gallons of lime-water		9 oz.		

"'A small residuum of the chalk always remains not separated by the process. Of 17½ grains, for instance, contained in a gallon of water, only 16 grains would be deposited, and 1½ grains would remain. In other words, water with 17½ degrees of hardness arising from chalk, can be reduced to 1½ degrees, but not lower.

"'These explanations will make it easy to comprehend the successive parts of the softening process.

"'Supposing it was a moderate quantity of well-water from the chalk strata around the metropolis that we had to soften, say 400 gallons. This quantity, as has already been explained, would contain one pound of chalk, and would fill a vessel four feet square by four feet deep.

"'We would take nine ounces of burnt lime made from soft upper chalk; we first slack it into a hydrate by adding a little water. When this is done we would put the slacked lime into the vessel where we intend to soften, then gradually add some of the water in order to form lime-water. For this purpose at least 40 gallons are necessary, but we may add water gradually till we have added thrice as much as this; afterwards we may add the water more freely, taking care to mix intimately the water and the lime-water or lime. Or we might previously form saturated lime-water, which is very easy to form, and then make use of this lime-water instead of lime, putting in the lime-water first and adding the water to be softened. The proportion in this case would be one bulk of lime-water to 10 bulks of the hard water.

"'It is of importance that the lime or lime-water, that is, the softening ingredient, be put into the vessel first, and the hard water gradually added, because there is thus an excess of lime present up to the very close of the process, and this circumstance is found to render the precipitation of the carbonate of lime produced in the process more easy.

"'But what you will wish to know now is, by what mark is the conductor of the process to find out when there is enough of water to take up the last of the excess of lime, so as to be enough, but no more.

"'This is done by what has been called the silver test, the only test necessary to the operator after the process is fairly set a-going This test is a solution of nitrate of silver in twice-distilled water, in the proportion of an ounce per pint. In making use of the silver test with ordinary waters, we get a white precipitate, but if the water have in it a notable excess of lime-water, there is a light reddish-brown precipitate produced, but if the excess be very slight

This Report was written 24 years ago, and the invention of Clark, having stood the test of that period of time, is as n approved at the present moment as it was then.

APPENDIX H.

THE SELF-ACTING SEWAGE REGULATOR OR AUTOMATIC SEWAGE METER.

Object of Invention.

The object of this invention is to regulate, automatically, the quantity of sewage or other liquid which may be applied to land, either for the purpose of utilisation or purification.

One of the most prominent difficulties which presents itself in the utilisation of sewage, is the very different quantity which is discharged from sewers at different times. In many towns and villages the flow will be diminished, at certain periods, to a mere dribble while at other times there will be a copious discharge.

Hence, as it is essential to economy in sewage farming that the crops should receive only that quantity of sewage which will produce the most fruitful growth, and as it is equally essential to success in intermittent filtration that the soil used to purify the sewage should receive only the quantity which it is capable of purifying, it becomes almost a necessity to have a means of regulating the quantity of sewage to be dealt with.

"The Self-Acting Sewage Regulator" performs this service in the most simple and perfect manner, during the night, as well as during the day, and without any supervision. The sewage is made to flow into a tank of such capacity, that when the liquid rises to a given level, the tank holds the precise quantity it is desired to deliver to a certain area of land at one time. This tank—called "the meter tank"—is provided with a syphon outlet, which is brought into action as soon as the liquid rises to the given level. When this is reached, the liquid flows out of the tank ("automatically") through the syphon, and continues flowing until the level of the liquid in the tank has fallen to the inlet mouth of the syphon, when air is drawn or admitted into the syphon, and the discharge ceases. The sewage flowing into the tank then commences to fill it again—slowly or quickly, according to the rate of influx—and as soon as it is full, the automatic discharge will be repeated, and the liquid can be applied either to the same area of land, or to another, as desired.

The coarser matters floating in the sewage are intercepted in a separate chamber, called "the intercepting chamber," before the meter tank is reached—the finer particles being carried forward with the liquid through the strainer, into the meter tank.

If it be desired to effect a precipitation of these finer particles, the space in the meter tank below the inlet mouth of the syphon is increased in depth, so as to form a receptacle, for any amount of deposit which it may be determined to precipitate and consolidate. In such case the space above the inlet mouth of the syphon will be occupied by clarified liquid, to be discharged on to land automatically by the syphon, as already described, while the space below the said inlet mouth will serve as a receptacle for the deposit, means being provided for draining off the liquid with which the precipitated particles are mixed, so as to allow of the consolidation of the deposit for removal. While this treatment of the solid portion is going on, the sewage is diverted by self-action into another meter tank.

The meter tanks are multiplied in number according to the quantity of sewage under treatment and the use to which the precipitated matter is to be applied. Where the quantity of deposit is trifling, it can be flushed out from the meter tank periodically without consolidation, and applied directly to the land.

The self-acting sewage regulator is applicable to small towns and villages, isolated country mansions, asylums, hospitals, schools, and other public buildings, where the flow of sewage is not only variable, but at times so small as almost to prevent its even distribution over land.

No night labour is necessary. Before leaving the land, the man in charge of the sewage need only "set his stops" in the carriers and furrows to secure the even distribution of the next discharge of sewage over the precise area to which it is intended it should be applied.

The simplicity of the invention will be manifest from this description, and it will be seen that, in addition to regulating the quantity of sewage automatically, and in the most perfect way, the syphon delivers the sewage in precisely the manner most suitable for irrigation or intermittent filtration—viz., at a gradually decreasing rate of discharge. Thus, at the commencement of the action of the syphon, when the carriers are empty, the land dry, and the absorption of sewage rapid, the discharge is rapid; and at the end of the action, when the carriers are full, the land wet, and the absorption of sewage comparatively slow, the discharge is slow.

Eastwick Sewage Works.

EXTRACT from the Report of Mr. Netten Radcliffe, Medical Inspector of the Local Government Board, upon "Certain Means of Preventing Excrement Nuisances in Towns and Villages," (See Supplemental Report of the Medical Officer of the Local Government Board and Privy Council. New Series. Part II. 1874.)

"The same difficulties have been experienced in dealing with and utilising readily, economically, and inoffensively, the liquid house refuse of villages and towns, as with that of separate houses, and from the same causes, the ordinary insignificance, and occasional irregularities of flow. To meet these difficulties Messrs. Bailey Denton and Field have designed a tank termed by them 'The Automatic Sewage Meter,' which is constructed on the same principles as Mr. Field's self-acting flush-tank. This 'meter' provides for the accumulation of the liquid refuse and for its automatic discharge at definite intervals, in quantities admitting of distribution over land by gravitation, for purposes of irrigation. A meter of this kind has been in use about three years in the hamlet of Eastwick, near Leatherhead, in Surrey, and its operation, particularly as part of the sanitary arrangements of the village, may there be studied very usefully.

"Eastwick is a hamlet of thirteen houses, including the mansion of the proprietor and the farm homestead; and it has a population of about 145. In devising a system of excrement and slop disposal for the place, any general plan of water sewage had to be set aside, the water supply derived from wells being variable in quantity, and at no time too abundant for ordinary domestic use, irrespective of water-closets. The common privy was retained for the cottages, but the privy-pit was converted into a water-tight receptacle beneath the floor of the closet, and the cottagers were instructed to throw into it above the excrement the refuse ashes, and to remove the contents of the pit monthly for use in their gardens. Four water-closets exist and five earth-closets for the use of the mansion and its precincts; and the water-closet and three earth-closets for the use of the farm homestead. To provide for the liquid house refuse of the hamlet, and for the drainage of the farm buildings, the scheme of sewage was carried out by Mr. Bailey Denton, and which has an outlet in a meter tank." (See Drawings II. and III. Appendix.)

"The tank is in two compartments, to admit of cleansing without entire disuse. It has a capacity of 500 gallons, and it fills and dis-

charges in ordinary dry weather three times in two days. The s
discharges are directed successively on different portions of
of ground prepared for the purpose, and which measuring three
three perches serves ordinarily for the effective and profitable
sation of the whole liquid refuse of the several cottages, the ma
and the farmstead. The drainage of the latter includes th
from cattle sheds and stables, in which from fifteen to twenty an
are always present, and about thirty head of horned cattle
thirty horses at intervals. The drainage of a large piggery
passes to the tanks.

"Luxuriant crops have been grown upon the irrigated land
year's crop consisting of the thousand-headed cabbage. Of
crop, Mr. Hutchinson, the steward of the estate, says: 'Be
thriving so well upon the sewage, it is an excellent food for
cows, being less strong in taste than the drumhead and not ha
any but a good effect upon the milk. The thousand-head can
be used as human food. I estimate the value of the crops obt
at 25*l.* per annum, or at the rate of 32*l.* 10s. per acre; and the
lay in attendance upon the land and the regulator ('meter')
down at 7*l.* 16s.'

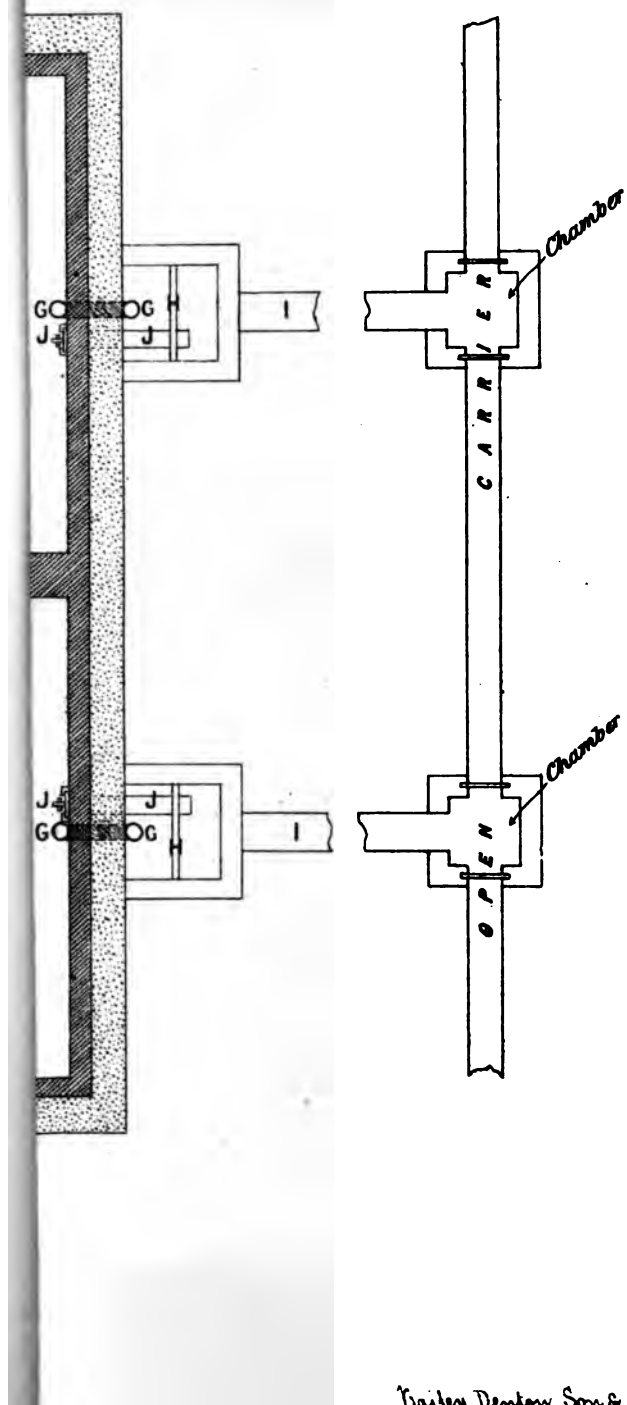
* * * * * *

"In regard to abatement of slop nuisance, and I may add
largely of farm nuisance, among a rural community, the arra
ments at Eastwick are the most complete and satisfactory I
yet seen. Notwithstanding the contiguity of the irrigated lan
the mansion, no nuisance is experienced from it, whereas prev
to the present arrangements, when the slops of the mansion
cottages found their way into neighbouring ditches and decomp
there, considerable nuisance had existed. With some struc
alterations in the privies (the principles of which are stated in
proper place in this report) and such needed supervision as will
be obtained from the sanitary authority appointed under the P
Health Act, 1872, the arrangements at Eastwick may be rega
as a pattern to be followed by villages and small towns simi
circumstanced.

"From what has already been said it may be inferred that the
tomatic sewage meter' admits of wide application in removing
difficulties which often beset the disposal of the sewage of com
nities larger than Eastwick. It simplifies the whole questio
dealing with the sewage of small towns, villages, isolated ins
tions, and mansions, while securing the most efficient applicati
the sewage to land, both for purification and utilisation, with
least expenditure of labour."

Sanitary Engineering:- **THE DWELLING.**

Appendix, Drawing II.



Bailey Denton Son & North.
22 Whitehall Place. London

APPENDIX I.

DETAILS OF THE QUANTITY OF EXCRETA AND REFUSE MATERIAL COLLECTED BY MR. ALDERMAN TAYLOR'S SYSTEM OF SCAVENGING AT ROCHDALE, AND THE COST THEREOF, WITH OTHER PARTICULARS OF A SIMILAR SYSTEM ADOPTED AT THE TOWNS OF WARRINGTON, BIRMINGHAM, NOTTINGHAM, AND BLACKBURN.

(*Extracted from the Proceedings of the Sewage Conference held by the Society of Arts, May*, 1876.)

ROCHDALE.

At Rochdale "the number of closets at this date is 5644, and the excreta contained in these, the refuse, including ashes, from the house, are systematically collected weekly, or oftener, without any notice being required from the householder, and the whole is utilised by being made into manure, mortar, cement, or fuel. Thus the whole of the refuse collected is utilised, and the nuisance of a tip obviated.

"The quantities collected weekly vary as the system is extended. Last week, ending April 12th, the quantities were 118 tons of excreta and 208 tons of refuse material, from an estimated population of 52,000, and the weekly cost 74*l.*, excluding interest and depreciation, or 4s. 7½d. per ton, or 30*l.* per 1000. The total excreta collected last year was 5398 tons, and of refuse 8652 tons. The work is done by 18 carters, 18 guards, 18 horses, 3 washers, 1 labourer, 4 inspectors, 1 horsekeeper, and 1 bookkeeper.

"On the manufacture there are employed 5 men to riddle and wheel away, 6 to form the trenches and turn over the manure, 2 to empty the vans, 2 labourers, 1 engineer, 1 foreman, 1 bookkeeper, the weekly cost being 24*l.* The product of the manufacture and separation is 84 tons of manure, 120 tons cinders, and 8 tons vegetable and other matter; the value being 84*l.* for manure, 2*l.* for mortar, and 2*l.* cinders, for sale.

"To the whole cost of collection and manufacture, and sale, would have to be added interest and depreciation.

"The machinery at present in use consists of two steam engines, of eight and four-horse power respectively, a riddle for sifting the refuse, a mortar mill, a boiler for evaporation of urine, a small fan for ventilation and blowing, and a furnace for burning the refuse. The capital expended is for building and machinery, 200*l.*; and for horses, vans, &c., 1975*l.* The manufacture does not cause any nuisance outside the premises.

"The manure made by the process detailed will be of an average theoretical value of 22s. to 25s. per ton. This value is increased to 3*l.* or any intermediate price, by the addition of blood manure, and also by the evaporation of urine collected from the urinals of the town. This has not been done largely, but will soon become a great addition to the strength. The urine is mixed with sulphuric acid, and reduced until it gives by analysis 10 per cent of ammonia.

"The sanitary improvement is undoubted, as shown by the diminished death-rate. In the six years previous to the commencement of the system, that is from 1864 to 1869, the death-rate was at the average of 26·22. In the last six years, from 1870 to 1875, the death-rate has been reduced to 23·57.

"The state and yearly progress of the system is seen in the Table below.

Year ending March 31st.	Number of Closets.	Collected.		Manure.		Houses.	Mill and Workshops.	Number of Persons using the Privies.	Gross Expenditure.	Manure Made.	Net Cost.
		Excreta. Tons.	Ashes. Tons.	Made. Tons.	Sold. Tons.						
1870...	527	398	611	377	217	1048	12	5,797	694	537	157
1871...	1070	846	1521	1059	699	2944	31	11,770	1538	1380	158
1872...	1690	1431	2405	1556	1019	3174	39	19,283	2392	2167	225
1873...	2509	1989	3413	1989	142	4560	69	26,984	3463	2826	637
1874...	3980	3516	5196	3479	1543	7287	106	43,500	5284	4449	835
1875...	4741	4224	7650	3741	2002	8487	123	50,000	7057	4420	2637
1876...	5566	5398	8652	755	2140	9436	146	52,000	...	...	...

Warrington.

"Until 1872 the old midden system was in use; pail system has now been adopted; about 2,200 pail-closets now employed; night-soil mixed with ashes and sold to farmers. There was a net loss to the town of from 600*l.* to 700*l.* in disposing of the nightsoil in 1875. The pail system has been found to be the best method of disposing of the nightsoil in this locality.

"STATEMENT showing Cost of Working the Nightsoil Branch of the Scavenging Department, for the Year ending 31st August, 1875.

Dr.	£	s.	d.	Cr.	£	s.	d.	£	s.	d.
By Interest on 698*l.*, purchase of land for depôt, and weighing machine, &c., at 5*l.* per cent...	34	18	0	By Cash received for nightsoil	1697	3	11			
„ Do. on 798*l.* for purchase of vans, horses, &c., at 20 per cent.	159	12	0	„ Accounts owing for nightsoil, 31st August, 1875	376	0	0			
„ Wages of inspector	91	0	0	Estimated value of nightsoil at depôt...	368	0	0			
„ Do. of nightsoil men...	1064	4	0		2441	3	11			
„ Cartage, including drivers' wages, provender, shoeing, hired horses, &c.	1122	8	7	Deduct £ s. d.						
„ Sundry other charges	91	0	0	Accounts owing for nightsoil, August 31, 1874 350 0 0						
				Estimated value of nightsoil at depôt at the same date.. ... 279 3 0						
					629	3	0			
								1812	0	11
				Net cost of working the branch				751	1	8
	2563	2	7					2563	2	7

Selling price of manure at the works, 4s. per ton."

BIRMINGHAM.

At Birmingham, there are " 19,000 middens, 3,977 ash-tubs, and 9,184 pail-closets on the Rochdale system, with some modifications; nightsoil mixed with ashes, part is sold to farmers, the remainder is deposited at depôts in the country. Ashes, when collected, are screened, the fine ash is mixed with the contents of excreta vessels, the mixture is then sold to farmers as manure. Gross cost of dealing with nightsoil in 1875, 35,301*l.*; receipts, 5,795*l.*; estimated expenditure for the year 1876 for scavenging, repairing, and watering the streets, 50,250*l.*, of which amount 15,500*l.* is for stone for macadamising purposes. The Rochdale system has been found to be, in this locality, the best method of disposing of nightsoil.

" Mr. J. Netten Radcliffe's report for 1874, states; 'Pail system introduced May, 1873; at present time 2,700 pail-closets in use; pails changed weekly; manure made from mixed excrement and fine coal-ash, sells at 5*l.* per cart-load of from 24 to 25 tons; 27,644 middensteads and ash-pits cleansed in 1873; 163,142 loads of soil removed; cost 24,000*l.*, less 3,500*l.* received for sale of part of removed material; estimated cost of working pail system in the borough, including interest on capital account and depreciation, would not exceed cost of present nightsoil scavenging by more than 2,000*l.*, while receipts from sale of manufactured manure and rough

ashes would realise probably 18,000*l.*, without including cost of manufacture.' "

Nottingham.

At Nottingham, where there are about 3,766 tub-closets and 6,000 middens and ash-pits, the nightsoil is "collected and sold to farmers under the direction of the officers of the corporation. Gross cost of disposing of nightsoil in 1875, for cleansing privies and ash-pits, 5,981*l.* 1s. 4d.; for tub-closets, 1,791*l.* 12s. 4d.; for purchase of horses and plant, 815*l.* 5s. 4d.; and for repairs, 560*l.* 11s. 3d.; total 9,148*l.* 10s. 3d.; receipts, 4,284*l.* 19s. 8d.; cost of scavenging, 2,300*l.* System in present use not objectionable in a sanitary sense, financially an annual loss. It is hoped, however, that when present works are completed, expenses will be reduced.

" Mr. J. Netten Radcliffe's report for 1874 states: 'Number of pail-closets 2,510, serving for the use of 4,516 houses. This form of closet is now regularly adopted in the old town, when a new privy is to be erected, or an old privy to be reconstructed. A single pail is used for excrement, ashes, and dry house refuse.' "

Blackburn.

At Blackburn there are "15,770 pails; ashes mixed with nightsoil after collection and sold to highest bidder; gross cost of disposing of nightsoil in 1875, 5,641*l.*; receipts, 773*l.* 17s. 5d.; scavenging, 2,098*l.* 15s. 2d."

Mr. Bryan, the borough engineer of Blackburn, states, however, that in that town this system of collection involves "a most abominable stench."

APPENDIX J.

NORWICH WATER WORKS COMPANY.

Rules and Regulations.

"1. The company will, at their own cost, lay down and maintain all the lead or other branches extending from their main to the side of the public highway in which such main is situate; and will, at their own cost, carry the pipe through the frontage wall (if there be one), and six inches beyond, or otherwise equivalently allow fifteen inches in length for the owner's or occupier's plumber to connect his work to.

"2. The owner or occupier must, at his own expense, lay down and maintain all the pipes and apparatus upon his premises or for his use, and of the strengths and descriptions, and subject to the rules following, that is to say:

"A. Such pipes must, unless otherwise agreed, be of lead, and of not less than the following weight, namely:

in.	lb.	
$\frac{3}{4}$	5	per yard.
1	7	"
$1\frac{1}{2}$	9	"
$\frac{3}{5}$	11	"
$\frac{1}{4}$	16	"
1	22½	"
$1\frac{1}{4}$		

"*Note.*—Owners and occupiers, before laying on the water or making alterations in their apparatus, are requested to inquire at the company's offices, the sizes of the pipes proper to be used, that such sizes may be duly proportioned to the pressure of water in the company's mains in the district, and thus useless expense be prevented.

"B. The drawing (bib) stop and ball-cocks must be strong and of hard brass, and the better to secure water-tightness, of the

kinds from time to time sanctioned and approved by the company; and unless and until due notification to the contrary, the drawing cocks must be of the best and now approved kind of those called 'screw-down cocks,' as manufactured by Messrs. Guest and Chrimes, and Messrs. Stocks, Brothers, and Taylor, with leather faces not liable to turn on the seat; and in courts of houses and other exposed places, must be protected by an iron casing, and be made to open with keys. And the ball-taps must be of the best and now approved kind, as manufactured by Messrs. Lambert and Sons, or by Mr. George Watson. Till otherwise notified, no other description of cock must be used without the previous and express permission of the company.

"C. Every cistern must be absolutely water-tight, and be provided with a ball-cock, and proper means of access and inspection, but must not have an overflow or waste-pipe; and if any such should exist, the same must be removed, or effectually and permanently closed before the water is turned on; but nevertheless, as exceptional instances will occasionally occur in which it will be necessary to provide against the possibility of overfilling, the company will, in such exceptional instances, allow a detective or warning pipe to be attached to the cistern, provided that in every such case a written consent must be first obtained from the manager of the company, stating the fact of such consent, and the position in which the detective or warning pipe must be fixed; and in every such case the work must be executed under the immediate superintendence of an officer of the company, and in the manner stated. On no account whatever can the water of the company be allowed to communicate with any cistern or place intended or used for the reception of rain-water.

"D. Water-Closets.—Every pan closet must be provided with a full and complete apparatus, comprising a ball-cock and a service cistern, fitted with a boot or division, to be carried as high as the top of the cistern, and capable of containing not more than one and a half gallons of water when filled within three inches of the top, and two proper valves, so arranged as to let down not more than one boot or division full of water at each pull, or be capable of allowing the water to run to waste either by intention or neglect; and must also have a down pipe of lead from the cistern to the basin of not less than $1\frac{1}{4}$ in. in diameter, and weighing 9 lbs. to the yard run; and a proper basin, scatterer, weighted lever, pan, trap, and other appliances, needful to prevent such water-closet from becoming a nuisance, and thereby inducing an

undue consumption of water; and the valves must be worked by brass rods instead of by wires or chains. Every self-acting, or pull-down water-closet, must be of a description approved by the company, and must have either a lead cistern similar to a pan closet, or a double valve cast-iron service box, of a kind approved by the company, and fitted with a proper cover to screw on, and internal apparatus in all respects similar to that of the boot of the pan closet above described, and a similar down pipe of lead or cast iron, and must have a proper wide-rim flushing basin and trap, of a kind approved by the company. No wire will be allowed to be used in the construction of these water-closets.

"The cast-iron double valve service boxes must be provided with a ball-tap of the approved kind, and of half an inch diameter where the pressure is less than 40 feet effective head; of three-eights of an inch diameter where the pressure is less than 70 feet effective head; and a ball-tap of a quarter of an inch diameter where the pressure is more than 70 feet effective head.

> "*Note.*—No pipe will be suffered, under any pretence whatever, to communicate directly or indirectly with the basin, or trap, or otherwise than with the cistern or service box of a water-closet or soil-pan, and the same shall be so constructed and used as to prevent the waste or undue consumption of water, and the return of foul air, and other noisome or impure matter, into the mains or other pipes of the company.

"E. Every bath must be constructed without an overflow or waste pipe, and must be provided with a well-fitted and perfectly water-tight apparatus, to prevent the water from flowing into and out of the bath at the same time.

"F. No pipe must be laid through, in, or into any sough, drain, ash-pit, manure hole, or other place, from which, in event of decay or injury to such pipe, the water of the company might be liable to become fouled, or to escape without observation or without occasioning the necessity of immediate repair. In every case in which any such sough, drain, ash-pit, manure hole, or other place as aforesaid, shall be in the unavoidable course of the pipe, such pipe shall be passed through an exterior cast-iron pipe, or box, of sufficient length and strength to afford due protection to the water pipe, and to bring any leakage or waste within the means of easy detection.

"G. Every pipe and apparatus laid and fixed by, or for the use of the consumer, must be inspected by an officer of the company before it is connected to the company's works; and, if found not in accordance with the company's regulations, must be forthwith removed or altered.

"H. Every meter (unless otherwise specially agreed) must be provided with a separate and distinct inlet pipe, leading from the main or other pipe of the company—upon which inlet pipe no stop-cock, except the stop-cock (if any) immediately attached to the meter, branch, drawing cock, or other outlet, leading to or connected with the premises for the supply of which such meter is fixed, will be permitted.

"3. The water supplied must not be allowed to run to waste, either wilfully or by neglect; nor must it be used for any other purpose, or to any greater extent, than shall have been agreed for.

"4. No pipe must be attached to the works of the company, or to any pipe or apparatus connected therewith; nor must any alteration be made in any existing pipe or apparatus, without due notice being given to, and the consent of the proper officer of the company being first obtained.

"5. The supply and use of water for the purpose of trade and manufacture, must be open to inspection and admeasurement whenever required; and such information must be from time to time afforded, as will be sufficient to enable the company to obtain a satisfactory account of the quantity of water actually consumed; and of the pipes, cocks, cisterns, and other apparatus, and conveniences for delivering, receiving, and using such water.

"6. The company will, if, and when so desired, execute all kinds of plumbers' work connected with the supply of water to their tenants, but are nevertheless desirous that the private business of the consumers of water shall be open to all the plumbers of the city; as, however, it is essential to the protection of the interest of the consumers, as well as of the company, that such work shall be well and soundly executed, and that the directors of the Water Works company shall possess a full and satisfactory knowledge of the state of the undertaking in all its departments, it is announced that no plumber or other workman will be allowed to do or perform any work connected with the supply of water, till he shall have been admitted, enrolled, and published by the directors, as "an authorised water works plumber:" and shall have entered into a written engagement to conform to and comply with the rules and regula-

tions of the company in relation to the construction and management of the works and fittings to which such rules and regulations shall from time to time apply; and all responsible master plumbers on expressing their willingness to comply with such rules and regulations, will be admitted immediately on signing an undertaking to that effect. If at any time afterwards any such plumber shall be found guilty of wilfully breaking or evading the said rules or regulations, either by himself or his workmen, or shall refuse to communicate any information required of him in regard to any work done by him, or his workmen, or under his superintendence, or on his responsibility, his name will be erased from the list of "authorised plumbers," and will be forthwith advertised as having been so struck off.

"7. No person is to be employed in or about the water works, or any pipe or apparatus connected therewith, who has not been admitted "an authorised plumber," or whose name shall have been struck off the list as aforesaid.

"8. The company will pay a reward of twenty shillings to any person who will give such information as shall lead to the conviction of any person who shall fraudulently attach any pipe or pipes to the pipes of the company; or to any pipe, cistern, or apparatus connected therewith; or to or into which the water of the company shall flow or proceed; or who shall fraudulently use or otherwise misappropriate the water of the company, or who shall knowingly permit the same to be fraudulently used or otherwise misappropriated.

"9. The company will also adequately remunerate any person who will communicate timely information to their officers, of any leakages or wastes of water, and whether the same be accidentally, negligently, or wilfully occasioned or suffered.

"10. The company do not permit their officers, servants, workmen, or agents to solicit or receive any fee or gratuity whatsoever, and desire to be informed with respect to any infraction of this regulation; and also in respect to any act of incivility, or any neglect of attention on the part of such officers, servants, workmen, and agents, or any of them."

APPENDIX K.

MANCHESTER CORPORATION WATER WORKS.

General Instructions to Authorised Plumbers.

" 1. Persons requiring a supply of water must, in the first instance, obtain from the superintendent or other authorised officer of the water works committee instructions as to the proper point for the introduction of the water on to the premises. Such persons must at their own cost provide, lay down, and maintain all service pipes and fittings which may be required within their premises, including one foot of lead service piping beyond the boundary thereof.

" 2. In case the service pipes are of lead, they are required to be of the following strength, viz:

¾	inch	diameter	5	lbs. per lineal yard.
½	"	"	6	" "
¾	"	"	9	" "
1	"	"	12	" "
1¼	"	"	16	" "

" 3. A stop-tap will be required to be affixed on the service pipe inside the premises, and as near to the entrance as possible; and in all places where the stop-tap is fixed in the ground, authorised plumbers will be required to fix over the same a small cast-iron guard box, to indicate the situation of such stop-tap, which box must be inserted with cement into a flag 18 inches square, and 3½ inches thick, in such a manner as to prevent its being removed without the flag. All stop-cock boxes must not be less than 14 lbs. weight, with a proper orifice therein for stamping, as per pattern, which may also be seen at the stamping office.

" 4. Private service pipes are required to be laid three feet below the surface of the ground, and also to be brought out through the boundary of the private premises three feet below the street or roadway, and in default of this regulation being complied with, the pipes will not be connected by the corporation.

" 5. Before the connection for the supply of water can be made, or before any additional fittings can be connected to an existing service pipe, the work must be inspected and approved by the proper officers of the water works committee.

" 6. Printed forms will, upon application, be furnished to authorised plumbers, which they will be required to fill up and deliver at the water works office, as a notice of the fittings being ready for inspection, and also of any alterations made in existing service pipes or fittings.

" 7. None but proper valve taps are to be fixed, and of such a description as the water works committee may approve of.

" 8. Copper bit joints will not be allowed, but in all cases a proper wiped joint must be made.

" 9. No house or other premises will be allowed to have more than one supply pipe, either from the main, or from any adjoining premises.

" 10. No steam-engine boiler, or any description of closed boiler will be allowed to be supplied direct from the service pipe, but a cistern must be provided in every case, and the supply taken therefrom.

" 11. No water-closet or urinal will be allowed to be supplied direct from the service pipe, but must be supplied from a cistern: and no water-closet can be supplied by stop-tap or bib-tap, but must be provided with a proper valve apparatus. All urinals must hereafter be supplied by means of a cistern and pull, of the pattern made by Mr. Heyworth, of No. 59, Faulkner-street, Manchester; or that made by Messrs. Guest and Chrimes, of Rotherham, which have been approved of by the water works committee. Samples of these cisterns may be seen in work at the Water Works Stamping Office, No. 41, Bootle-street, Albert-square.

" 12. No tap for domestic purposes in dwelling-houses, or for drinking purposes in warehouses, will be allowed to be supplied from a cistern, but in all such cases drawing-off taps must be fixed on the service pipe before it enters the cistern; baths, water-closets, urinals, and wash basins only are allowed to be supplied from a cistern.

" 13. Cisterns must in every case be supplied by means of ball-taps.

" 14. The water works committee will provide and fix all water meters, and will also lay the service pipes from the boundary of the premises to the inlet of the meters and fix the stop-cocks thereon, at the expense of the occupier of the premises.

"15. Dwelling-houses must be supplied by service pipes of the diameter stated below, which rule all authorised plumbers are hereby instructed to carry out, viz.:

"$\frac{3}{8}$-inch. One house above 10*l.*, and not exceeding 20*l.* per annum rent, or not more than two cottages not exceeding 10*l.* per annum each.

"$\frac{1}{2}$-inch. One house above 20*l.* per annum rent, but not exceeding 70*l.* per annum. Six houses in one block may be supplied by this size of pipe, but the rents must not exceed 14*l.* per annum each.

"$\frac{3}{4}$-inch. One house from 70*l.* to 200*l.* per annum, but not more than four houses together at 50*l.* per annum each. Seventeen houses in one block, may be supplied from this size pipe, if the rents do not exceed 12*l.* per annum each.

"N.B. The full diameter of pipe must be continued through the whole of the houses supplied together.

"Where dwelling-houses are situated beyond the limits of the city, and in which no trade is carried on, and are supplied together from one service pipe, the owner will be liable to the payment of the water rent. The city comprises the following townships: Manchester, Hulme, Chorlton-on-Medlock, Cheetham, Ardwick, and Beswick.

"16. The water works committee will not sanction any fire-cocks or hydrants being fixed inside private premises, either from the main or from any cistern supplied with water by the corporation; at the same time they will consider any application for permission to attach any private stand-pipe and hose to the street hydrants, to be used in case of fire only.

"17. Information from authorised plumbers, or other parties, as to any infringement of the preceding instructions will receive the immediate attention of the committee.

"18. Authorised plumbers will be struck off the list if found lending their names to unauthorised persons.

"TESTING AND STAMPING ARRANGEMENTS.

"Stamping Office: No. 41, Bootle-street, Albert-square.

"*Testing and Stamping Internal Water Fittings.*

"The following regulations must be complied with:

"1. All taps and other water fittings must be tested and stamped by the proper officer of the corporation.

"2. No taps or apparatus will be stamped but those of the best quality of each maker, samples of which will be kept for inspection at the stamping office.

"3. The taps must be on the screw-down principle, with loose valves and stuffing boxes; the diameter of all orifices in the seat on which the valves work in the stop-taps to be the same size as the taps themselves; and all taps must be capable of resisting a pressure of 300 lbs. to the square inch to which they will be subjected in testing.

"4. The bib and stop-taps must be of the following average weights, viz.:

1 inch	. . . . .	32¼ ounces.
¾ "	. . . . .	21 "
½ "	. . . . .	11½ "
⅜ "	. . . . .	8½ "

"Double valve bib-taps:

¾ inch	. . . . .	22¾ ounces.
½ "	. . . . .	13¼ "
⅜ "	. . . . .	10¼ "

"5. Ball-taps must be the best quality, and the diameter of the pipe and ball as under:

1 inch	diameter of pipe, not less than	6 inches	diameter of ball.
¾ "	"	5½	"
½ "	"	4½	"
⅜ "	"	4½	"

"6. The rods or spindles from the balls to the taps must not be less than the following lengths:

1 inch	diameter of tap,	13	inches long.
¾ "	"	13	"
½ "	"	11	"
⅜ "	"	11	"

"7. The strength of such rods or spindles must not be less than as follows:

End next the tap.		*End next the ball.*
1 inch	⅛ by ⅝ inches . .	⅒ by 7/32 inch.
¾ "	13/32 " 7/32 " . . .	ditto.
½ "	13/32 " 6/32 " . . .	⅒ by 5/32 inch.
⅜ "	11/32 " 6/32 " . . .	ditto.

"The rods or spindles referred to above may be of the following strength, in lieu of those stated, viz. $\frac{4}{10}$ by $\frac{3}{10}$ inch.

"8. Such taps without balls or spindles must not be less than the following weights:

1 inch	. . . .	$22\frac{1}{2}$ ounces.
$\frac{3}{4}$ "	. . . .	$10\frac{3}{4}$ "
$\frac{1}{2}$ "	. . . .	$7\frac{3}{4}$ "

"9. Cisterns for water-closets must be of the principle known as 73x, for common hopper closets, and of 73NT for the usual pan-closets, of Guest and Chrimes' make, or of other approved makers containing two alternating valves on the same principle, and constructed not to deliver more than $1\frac{1}{2}$ gallons of water at a flush, the pulls of which cisterns must be so constructed as to prevent their being fixed in any position to allow the water to be left running to waste.

"10. The overflow pipes of all cisterns hereafter fixed must act as warning-pipes, and must be brought through the external wall of the premises supplied with water at such a conspicuous point below the level of the bottom of the cistern as may be directed, and there properly maintained, which pipe must be of sufficient diameter to deliver any water wasting from the different diameters of ball-taps when out of order.

"11. Every cistern which shall be used for the storage or reception of water supplied by the corporation shall be made, and at all times maintained, absolutely water-tight, and shall be provided with a ball-tap, which must be branched into the inlet pipe thereof, and the latter made secure to the side of the cistern, as a connection to the end of such pipe will not be allowed. The ball-tap shall be so fixed as not to become submerged when the cistern is full; the level of the water at which time shall always be maintained at two inches below the overflow or warning-pipe; and every such cistern shall be made capable of inspection.

"12. Every overflow or waste-pipe which shall be attached to any cistern in use previous to the 1st of January, 1871, shall be altered in accordance with Regulation No. 10, after the corporation shall have given to, or left at the last known place of abode of the person liable to pay for the water supplied to such cistern, twenty-four hours' notice in writing, requiring such overflow or waste pipe to be so altered in accordance with the regulation referred to.

"13. Every bath to which water is supplied by the corporation shall be provided with a well-fitted and perfectly water-tight ground

outlet plug, with chain complete, or such tap as shall be approved and stamped.

"14. No overflow pipes other than such as are made to act as detective or warning pipes, previously referred to in Regulation No. 10, shall be made or attached to any bath in which water supplied by the corporation shall be used; and every overflow pipe which is now attached to any such bath shall be permanently altered to the satisfaction of the corporation, after they shall have given to, or left at the last known place of abode of the person liable to pay for the water supplied to such bath, twenty-four hours' notice in writing, requiring such overflow pipe to be so altered.

"15. Makers of or dealers in taps are requested to put their names on such as are of the best quality, as none others will be stamped.

"The following fees will be charged for testing and stamping:

Bib and stop-taps . . .	2d. each.
Ball-taps	3d. „
Water-closts	6d. „
Closet cisterns	3d. „
Stop-cock boxes . . .	2d. „

"By order of the Water Works Committee,

"JOSEPH HERON, Town Clerk.

"Water Works Offices, Town Hall, Manchester,
January 2, 1872."

APPENDIX L.

EXTRACT FROM THE "WATER WORKS CLAUSES ACT, 1847."

(*Clauses* 54 *to* 60.)

"If by the Special Act it be provided that the water to be supplied by the undertakers need not be constantly laid on under pressure, every person supplied with water shall, when required by the undertakers, provide a proper cistern to hold the water with which he shall be so supplied, with a ball and stop-cock in the pipe bringing the water from the works of the undertakers to such cistern, and shall keep such cistern, ball, and stop-cock in good repair, so as effectually to prevent the water from running to waste; and in case any such person shall, when required by the undertakers, neglect to provide such cistern, ball, or stop-cock, or to keep the same in good repair, the undertakers may cut off the pipe or turn off the water from the premises of such person until such cistern and ball and stop-cock shall be provided or repaired, as the case may require.

"Every person supplied with water by the undertakers who shall suffer any such cistern, pipe, ball, or stop-cock to be out of repair so that the water supplied to him by the undertakers shall be wasted, shall forfeit to the undertakers for every such offence a sum not exceeding 5*l*.

"The undertakers may repair any such cistern, pipe, ball, or stop-cock so as to prevent any such waste of water, and the expenses of such repair shall be repaid to them by the person so allowing the same to be out of repair and may be received as damages.

"The surveyor, or any other person acting under the authority of the undertakers, may, between the hours of nine of the clock in the forenoon and four of the clock in the afternoon, enter into any house or premises supplied with water by virtue of this or the Special Act, in order to examine if there be any waste or misuse of such water, and if such surveyor or other person at any such time be refused admittance into such dwelling-house or premises for the purpose aforesaid, or be prevented from making such examination

as aforesaid, the undertakers may turn off the water supplied by them from such house or other premises.

"Every owner or occupier of any tenement supplied with water under this or the Special Act, who shall supply to any other person or wilfully permit him to take any such water from any cistern or pipe in such tenement unless for the purpose of extinguishing any fire, or unless he be a person supplied with water by the undertakers, and the pipes belonging to him be, without his default, out of repair, shall forfeit to the undertakers for every such offence a sum not exceeding 5*l.*

"Every person who, not having agreed to be supplied with water by the undertakers, shall take any water from any reservoir, watercourse, or conduit belonging to the undertakers, or any pipe leading to any such reservoir, watercourse, or conduit, or from any cistern or other like place containing water belonging to the undertakers other than such as may have been provided for the gratuitous use of the public, shall forfeit to the undertakers for every such offence a sum not exceeding 10*l.*

"Every person who shall wilfully or carelessly break, injure, or open any lock, cock, valve, pipe, work, or engine belonging to the undertakers, or shall flush or draw off the water from the reservoir or other works of the undertakers, or shall do any other wilful act, whereby such water shall be wasted, shall forfeit to the undertakers for every such offence a sum not exceeding 5*l.*"

EXTRACT FROM THE "WATER WORKS CLAUSES ACT, 1863."

(*Clauses* 16 *to* 20.)

"And with respect to the waste or misuse of the water supplied by or belonging to the undertakers, be it enacted as follows:

"If any person supplied with water by the undertakers wrongfully does, or causes or permits to be done, anything in contravention of any of the provisions of the Special Act, or wrongfully fails to do anything which under any of those provisions ought to be done for the prevention of the waste, misuse, undue consumption, or contamination of the water of the undertakers, they may (without prejudice to any remedy against him in respect thereof) cut off any of the pipes by or through which water is supplied by them to him, or for his use, and may cease to supply him with water, so long as the cause of injury remains or is not remedied.

"If any person supplied with water by the undertakers wilfully or negligently causes or suffers any pipe, valve, cock, cistern, bath,

soil-pan, water-closet, or other apparatus or receptacle to be out of repair or to be so used or contrived as that the water supplied to him by the undertakers is or is likely to be wasted, misused, unduly consumed, or contaminated, or so as to occasion or allow the return of foul air, or other noisome or impure matter into any pipe belonging to or connected with the pipes of the undertakers, he shall for every such offence be liable to a penalty not exceeding 5*l*.

" If any person—

" First, not having from the undertakers a supply of water for other than domestic purposes, uses for other than domestic purposes any water supplied to him by the undertakers; or,

" Secondly, having from the undertakers a supply of water for any other than domestic purposes, uses, for any purposes other than those for which he is entitled to use the same, any water supplied to him by the undertakers, he shall for every such offence be liable to a penalty not exceeding 40s., without prejudice to the right of the undertakers to recover from him the value of the water misused.

" It shall not be lawful for the owner or occupier of any premises supplied with water by the undertakers, or any consumer of the water of the undertakers, or any other person, to affix or cause or permit to be affixed any pipe or apparatus to a pipe belonging to the undertakers, or to a communication or service pipe belonging to or used by such owner, occupier, consumer, or other person, or to make any alteration in any such communication or service pipe, or in any apparatus connected therewith, without the consent in every such case of the undertakers; and if any person acts in any respect in contravention of the provisions of the present section, he shall for every such offence be liable to a penalty not exceeding 5*l*., without prejudice to the right of the undertakers to recover damages from him in respect of any injury done to their property, and without prejudice to their right to recover from him the value of any water wasted, misused, or unduly consumed.

" If any person, not being supplied with water by the undertakers, wrongfully take or uses any water from any reservoir, watercourse, conduit, or pipe belonging to the undertakers, or from any pipe leading to or from any such reservoir, watercourse, conduit, or pipe, or from any cistern or other like place containing water belonging to the undertakers or supplied by them for the use of any consumer of the water of the undertakers, he shall for every such offence be liable to a penalty not exceeding 5*l*."

APPENDIX M.

REGULATIONS MADE UNDER THE "METROPOLIS WATER ACT, 1871."

"1. No communication-pipe for the conveyance of water from the water works of the company into any premises shall hereafter be laid until after the point or place at which such communication-pipe is proposed to be brought into such premises shall have had the approval of the company.

"2. No lead pipe shall hereafter be laid or fixed in or about any premises for the conveyance of or in connection with the water supplied by the company (except when and as otherwise authorised by these regulations, or by the company), unless the same shall be of equal thickness throughout, and of at least the weight following, that is to say:

Internal Diameter of Pipe in Inches.	Weight of Pipe in lbs. per Lineal Yard.
$\frac{3}{8}$ inch diameter . .	5 lbs. per lineal yard.
$\frac{1}{2}$ " " . .	6 " "
$\frac{5}{8}$ " " . .	$7\frac{1}{2}$ " "
$\frac{3}{4}$ " " . .	9 " "
1 " " . .	12 " "
$1\frac{1}{4}$ " " . .	16 " "

"3. Every pipe hereafter laid or fixed in the interior of any dwelling-house for the conveyance of, or in connection with, the water of the company, must, unless with the consent of the company, if in contact with the ground, be of lead, but may otherwise be of lead, copper, or wrought iron, at the option of the consumer.

"4. No house shall, unless with the permission of the company in writing, be hereafter fitted with more than one communication-pipe.

"5. Every house supplied with water by the company (except in cases of stand-pipes) shall have its own separate communication-pipe. Provided that, as far as is consistent with the special Acts of he company, in the case of a group or block of houses, the water-

rates of which are paid by one owner, the said owner may, at his option, have one sufficient communication-pipe for such group or block.

" 6. No house supplied with water by the company shall have any connection with the pipes or other fittings of any other premises, except in the case of groups or blocks of houses, referred to in the preceding regulation.

" 7. The connection of every communication pipe with any pipe of the company shall hereafter be made by means of a sound and suitable brass screwed ferrule or stop-cock with union, and such ferrule or stop-cock shall be so made as to have a clear area of waterway equal to that of a half-inch pipe. The connection of every communication-pipe with the pipes of the company shall be made by the company's workmen, and the company shall be paid in advance the reasonable costs and charges of and incident to the making of such connection.

" 8. Every communication-pipe and every pipe external to the house and through the external walls thereof, hereafter respectively laid or fixed, in connection with the water of the company shall be of lead, and every joint thereof shall be of the kind called a plumbing or wiped joint.

" 9. No pipe shall be used for the conveyance of, or in connection with, water supplied by the company, which is laid or fixed through, in, or into any drain, ash-pit, sink, or manure hole, or through, in, or into any place where the water conveyed through such pipe may be liable to become fouled, except where such drain, ash-pit, sink, or manure hole, or other such place, shall be in the unavoidable course of such pipe, and then in every such case such pipe shall be passed through an exterior cast-iron pipe or jacket of sufficient length and strength, and of such construction as to afford due protection to the water-pipe.

" 10. Every pipe hereafter laid for the conveyance of, or in connection with, water supplied by the company, shall, when laid in open ground, be laid at least two feet six inches below the surface, and shall in every exposed situation be properly protected against the effects of frost.

" 11. No pipe for the conveyance of, or in connection with, water supplied by the company, shall communicate with any cistern, butt, or other receptacle used or intended to be used for rain-water.

" 12. Every communication-pipe for the conveyance of water to be supplied by the company into any premises shall have at or near

its point of entrance into such premises, and if desired by the consumer within such premises, a sound and suitable stop-valve of the screw-down kind, with an area of waterway not less than that of a half-inch pipe, and not greater than that of the communication-pipe, the size of the valve within these limits being at the option of the consumer. If placed in the ground such stop-valve shall be protected by a proper cover and guard-box.

" 13. Every cistern used in connection with the water supplied by the company shall be made and at all times maintained water-tight, and be properly covered and placed in such a position that it may be inspected and cleansed. Every such existing cistern, if not already provided with an efficient ball-tap, and every such future cistern shall be provided with a sound and suitable ball-tap of the valve kind for the inlet of water.

" 14. No overflow or waste-pipe other than a warning-pipe shall be attached to any cistern supplied with water by the company, and every such overflow or waste-pipe existing at the time when these regulations come into operation shall be removed, or at the option of the consumer shall be converted into an efficient warning-pipe, within two calendar months next after the company shall have given to the occupier of, or left at the premises in which such cistern is situate, a notice in writing requiring such alteration to be made.

" 15. Every warning-pipe shall be placed in such a situation as will admit of the discharge of the water from such warning-pipe being readily ascertained by the officers of the company. And the position of such warning-pipe shall not be changed without previous notice to and approval by the company.

" 16. No cistern buried or excavated in the ground shall be used for the storage or reception of water supplied by the company, unless the use of such cistern shall be allowed in writing by the company.

" 17. No wooden receptacle without a proper metallic lining shall be hereafter brought into use for the storage of any water supplied by the company.

" 18. No draw-tap shal in future be fixed unless the same shall be sound and suitable and of the screw-down kind.

" 19. Every draw-tap in connection with any stand-pipe or other apparatus outside any dwelling-house in a court or other public place, to supply any group or number of such dwelling-houses, shall be sound and suitable, and of the waste-preventer kind, and be protected as far as possible from injury by frost, theft, or mischief.

"20. Every boiler, urinal, and water-closet, in which water supplied by the company is used (other than water-closets in which hand flushing is employed), shall, within three months after these regulations come into operation, be served only through a cistern or service-box, and without a stool-cock, and there shall be no direct communication from the pipes of the company to any boiler, urinal, or water-closet.

"21. Every water-closet cistern or water-closet service-box hereafter fitted or fixed in which water supplied by the company is to be used, shall have an efficient waste-preventing apparatus, so constructed as not to be capable of discharging more than two gallons of water at each flush.

"22. Every urinal-cistern in which water supplied by the company is used other than public urinal cisterns, or cisterns having attached to them a self-closing apparatus, shall have an efficient waste-preventing apparatus, so constructed as not to be capable of discharging more than one gallon of water at each flush.

"23. Every down-pipe hereafter fixed for the discharge of water into the pan or basin of any water-closet shall have an internal diameter of not less than one inch and a quarter, and if of lead shall weigh not less than nine pounds to every lineal yard.

"24. No pipe by which water is supplied by the company to any water-closet shall communicate with any part of such water-closet, or with any apparatus connected therewith, except the service-cistern thereof.

"25. No bath supplied with water by the company shall have any overflow waste pipe, except it be so arranged as to act as a warning pipe.

"26. In every bath hereafter fitted or fixed the outlet shall be distinct from, and unconnected with, the inlet or inlets; and the inlet or inlets must be placed so that the orifice or orifices shall be above the highest water level of the bath. The outlet of every such bath shall be provided with a perfectly water-tight plug, valve, or cock.

"27. No alteration shall be made in any fittings in connection with the supply of water by the company without two days' previous notice in writing to the company.

"28. Except with the written consent of the consumer, no cock, ferrule, joint, union, valve, or other fitting, in the course of any communication-pipe, shall have a waterway of less area than that of the communication-pipe, so that the waterway from the water in the district pipe or other supply pipe of the company up to and through

the stop-valve prescribed by Regulation No. 12, shall not in any part be of less area than that of the communication-pipe itself, which pipe shall not be of less than a half-inch bore in all its course.

" 29. All lead warning-pipes and other lead pipes of which the ends are open, so that such pipes cannot remain charged with water, may be of the following minimum weights, that is to say:

½-inch (internal diameter)	. . .	3 lb. per yard.
¾ "	" . . .	5 "
1 "	" . . .	7 "

" 30. In these regulations the term communication-pipe shall mean the pipe which extends from the district pipe or other supply pipe of the company up to the stop-valve prescribed in the Regulation No. 12.

" 31. Every person who shall wilfully violate, refuse, or neglect to comply with, or shall wilfully do or cause to be done any act, matter, or thing, in contravention of these regulations, or any part thereof, shall, for every such offence, be liable to a penalty in a sum not exceeding 5*l*.

" 32. Where under the foregoing regulations any act is required or authorised to be done by the company, the same may be done on behalf of the company by an authorised officer or servant of the company, and where under such regulations any notice is required to be given by the company the same shall be sufficiently authenticated if it be signed by an authorised officer or servant of the company.

" 33. All existing fittings, which shall be sound and efficient, and are not required to be removed or altered under these regulations, shall be deemed to be prescribed fittings under the ' Metropolis Water Act, 1871.' "

APPENDIX N.

DESCRIPTION OF MR. DEACON'S WASTE WATER METER.

(*Extracted from the Report of* MR. F. J. BRAMWELL, C.E., F.R.S.)

"The meter proper consists of nothing more than a vertical truncated hollow cone, having its small end upwards, and containing within it a disc of the same diameter as the small end of the truncated cone; a central stalk on the upper surface of this disc is suspended from a fine German silver wire, which passes, practically water-tight, through a small hole in the upper part of the chamber above the cone, and is attached to a guided cross-head, carrying a pencil or tracer, and having above it a band passing over a pulley, and supporting on the other side of the pulley a weight, which is a determinate amount heavier than the cross-head and disc, when the disc is weighed in water, so that the weight always tends to draw the disc up to the top of the truncated cone. The inlet for water is in the chamber above the cone, the outlet proceeds from a chamber below its base.

"In the upper chamber there is a diaphragm, with openings to equalise the flow of the water.

"Assume that water is supplied to the meter, but that none is passing through it, because all the outlets are closed, then the weight will have raised the disc to the extreme point of its travel, and so that the disc fills up the aperture at the top of the cone. If now a cock in the outlet be opened, say to a small extent, water will seek to flow, but in endeavouring to do so it must press upon the disc, and send it downward to a larger part of the cone, and the point where the descent of the disc will cease will be that at which the annular area between the edge of the disc and the interior of the cone is sufficient, under the difference of pressure between the upper and the under side of the disc, to enable the required quantity of water to pass; and this pressure will obviously be, for the whole surface of the disc, exactly that which will balance the excess of the weight above the weight of the disc, weighed in water, and the

cross-head weighed in air. If the pressure were less than this the weight would cause the disc to rise until the annular area was so much diminished that the required pressure to balance the surplus weight was just adequate to drive through this annular opening the quantity of water being drawn from the outlet; on the other hand, if the pressure were greater than the surplus weight the disc would descend until the increase of annular area would be such that at the pressure equal to the surplus weight the quantity of water demanded would flow through. In this manner the point of rest for the disc, with the supposed quantity being drawn, would be self-found; and, similarly, if a less quantity or a greater quantity (within the limits of capacity of the meter) were drawn off, the disc would find its appropriate position of rest in the truncated cone, a position corresponding to the particular quantity passing through. But the tracer rises and falls with the disc, and if this tracer have a piece of paper presented to it, it will draw a vertical line on that paper, the length of which will indicate the rate at which the water is passing through the meter; and, if this paper be printed with horizontal lines representing hundreds and thousands of gallons per hour, then an inspection would show at which of these lines the tracer was standing, and would enable an observer at once to say—"Water is now passing through the meter at a velocity equal to 1000 gallons, or 3000 gallons per hour," as the case may be.

"The foregoing is the construction of the meter proper; but if no further provision were made there would not be left any other record than this, viz., that since the paper was put on the rate of consumption had at some time attained a point indicated by the length of the vertical line on the paper; but it would be impossible to say when the maximum recorded rate of consumption was reached, or for how long it endured. Such an apparatus would give a record analogous to that of a self-registering thermometer, as from this implement all that can be ascertained is that at some time since the index was last set the maximum temperature has been a certain number of degrees, but when this happened, or for how long it continued, there is no means of ascertaining.

"But if a further provision be made by which, as in the steam engine indicator, the paper presented to the tracer can be caused to move sideways, then the tracer will no longer describe a mere vertical line, but it will describe a line compounded of the lateral movement of the paper, and of the rise and fall of the tracer. In practice, Mr. Deacon causes the paper to move sideways in the manner employed in apparatus for automatically recording the pressure

of the wind, and other similar phenomena; and in the manner in which the 'pressure papers' of the governors of gas works are actuated, viz., by wrapping the paper round a vertical cylinder to which motion is given by a common clock movement, so that the cylinder makes exactly one revolution in the twenty-four hours. The paper is divided vertically by twenty-four 'hour lines,' representing the hours of the day and the night, and, as has already been said, is divided horizontally by lines indicating the rate of flow in gallons per hour, and thus an examination of the line made by the tracer shows what was the rate of flow at any time of the day or night."

INDEX.

A B C Sewage Process (See Native Guano Company).
Absorbent soils, proportion of rainfall thrown off, 29.
Abyssinian tube wells, 45, 114, 119.
Acland, Dr., 355.
Adams' sink trap, 97.
Adits in wells, yield of water from, 125.
Ague in fens, recurrence of, since execution of drainage works, 16.
Air, Division I.:
—— Sec. I. Constituents of normal air, 1.
—— II. Attainable standard of pure air, 1.
—— III. Quantity of air respired by human beings, 2.
—— IV. Of oxygen, 3.
—— V. Of carbonic acid, 3.
—— VI. Of foreign matters polluting the air, 6.
—— VII. Agencies counteracting the pollution of air, 7.
—— VIII. Ground air, 7.
—— IX. Malaria, 10.
—— X. Of carbonic acid as the measure of impurity of air, 11.
—— XI. The duty of the engineer in relation to air, 13.
—— XII. Dry and wet soils compared, 14.
—— XIII. Wet soils injurious to the health of districts, 16.
—— XIV. Improved temperature of the atmosphere secured by drainage of subsoil, 16.
—— XV. The maintenance of pure air in the vicinity of dwellings by under-drainage an object of importance, 18.
—— method of analysing, 13; Appendices A and B.
—— impure, effect of exposure to, 18.
—— of confined and open places, 4.
—— of marshes, 10.
Air, of sewers, 10.
—— of soils saturated with sewage, 8.
—— necessity of removal of subsoil water for maintenance of pure, 11 to 16, 18, 48 to 55.
Aldis, Dr., effect of wet soils upon health, 53.
Alexander's gully, 209.
Alkali works, composition of liquid refuse from, 255.
Allotment gardens, disposal of village sewage on, 183, 352.
Alpaca works, purification of liquid refuse from, 335.
Analysis of air, Pettenkofer's method, 13; Appendix B.
—— Angus Smith's method, 13; Appendix A.
—— water, classified results, 33.
Anderson's, Dr., process of sewage precipitation (see General Sewage Manure Company).
Antill's sink trap, 98.
Appliances used in connection with sewers, 199.
—— sinks, 91, 97.
—— water-closets, 71.
Ash-pit and dust-bin, necessity of frequent removal of contents of, 226.
Aston (Birmingham), well at, 114.
Atkins' block charcoal filter, 147.
Attraction (capillary) in soils, 54.
Automatic sewage meter, 63, 183, 339; Appendix H.
Aylesbury, native guano sewage process at, 278.

Bacon, Lord, as to site of dwelling, 48.
Bacup, water at, 22.
Ball valves, 239.
Banbury, reduction of phthisis at, 49.
Banks, J., charcoal in sewer ventilators, 215.
Banner's cowl, 108.

Barking, Lodge Farm at (see Lodge Farm).
Barlow's, Mr., rule for thickness of pipes, 166.
Barnicott and Kenyon, purification of trade refuse by, 334.
Barnsley, increase of population at, 166.
Barracks (English), air space required in, 106.
—— and hospitals, air of, 5.
Basements of dwellings rendered foul by leaky sewers, 51, 54, 164, 178.
Bateman, Mr. J. F., C.E., evaporation of rainfall from pervious and impervious soils, 29.
Bath, water at, 22.
Bavin dip trap, 94.
Bazalgette, Sir J., on "A B C" sewage process, 274.
—— road detritus, 206.
—— sewer velocities, 185.
—— surface waters admitted into metropolitan sewers, 155.
Beardmore's, the late Mr., formula for calculating discharge of circular culverts, 186.
—— sewer velocities, 185.
Bed system of sewage distribution, 315.
Beddington, sanitary condition of district near sewage lands at, 347.
Bedford, water at, 22.
—— sewage farming at, 260.
—— subsoil water reaching sewers of, 165.
Berkhampstead, details of well sunk at, 116.
Bidder, Mr. George, C.E., sewer velocities. 185.
Bird's process of sewage treatment, 290.
Birkenhead, water at, 22.
Birmingham, increase of population at, 166.
—— lime process at, 291.
—— pail system and scavenging at, 221; Appendix I.
—— road detritus collected from sewers at, 159, 266.
Blackburn, pail system at, 221; Appendix I.
Blackwell, Mr., C.E., sewer velocities, 185.
Blanket mill, liquid refuse from, 167, 255.
Bleach works, liquid refuse from, 255, 336.
Blyth, Professor, effect of impure water on animal economy, 20; Appendix C.
Bolton, value of sludge manure at, 269.
—— water at, 22.
Bombay, rainfall at, 22.
Bond's, Dr., dry closet, 100.
Borings in chalk and new red sandstone cost of, 114 to 117.
Boston, average monthly rainfall at, 23.
Boussingault on the value of sewage, 251
Bowditch, Dr. (U. S. A.), importance a dry soil, 14.
Box, Mr., formula for thickness of iron pipes, 196.
—— table of proportions of cast-iron flange pipes, 198.
—— table of proportions of joints for cast-iron socket pipes, 198.
Bradford, cost of chemical sewage process at, 261.
—— increase of population at, 166.
—— value of lime treated sludge at, 269.
Bramwell, Mr., C.E., on Deacon's water meter, Appendix N.
Brass and copper tube works, composition of liquid refuse from, 168, 255.
Brentnall, Mr., on Clarke's gully, 209.
Bretons Farm, investigation into enteron theory of Dr. Cobbold at, 349,
Brick sewers, 190.
Brighton, death-rate at, 178.
—— increase of population at, during fifty years, 166.
—— objections to sewage disposal works at 177.
Bristol, reduction of phthisis by drainage of soil at, 49.
—— water at, 22.
British Association Sewage Committee, 103, 285, 286, 298, 303.
Brooks' "drain sewer," 52.
Brownlow, Earl, water supply on the estate of, 116.
Brundell's, Mr., sewage farm at Doncaster, 257, 267.
Brussels, rainfall at, 22.
Buat's formula for calculating the discharge of culverts, 187.
Buchan, Mr., on the increase of temperature by drainage of soil, 17.
Buchanan, Dr., cause of phthisis, 14.
—— dry-closet systems, 225.
—— researches of in sanitary science, 355.
—— results of the lowering of subsoil water in certain towns, 15, 49, 53.
Buckham, Mr., C.E., on charcoal in sewer ventilators, 214.
Burnley, increase of population at, 166.
Burton-on-Trent, Abyssinian wells at, 122.
Butler and Askie's ball valve, 242.
Butt's gully, 209.
Byrne and Spon, Messrs., data by for cal-

culating the strength of iron pipes, 195.

Calder Valley, disposal of sewage in, 344.
Calico works, liquid refuse from, 335.
Cambridge, water at, 22.
Canterbury, water at, 22.
Capillary attraction, 54.
Carbon consumed in food by adults, 2.
Carbonic acid, 1 to 13.
—— in air of sewers, 10.
—— in confined and open spaces, 3 to 6.
—— Pettenkofer's method of ascertaining, 13; Appendix B.
—— Smith's (Dr. Angus), method of ascertaining, 13; Appendix A.
Cardiff, reduction of death-rate by removal of subsoil water at, 15, 49.
—— water at, 22.
Carlisle, subsoil water in sewers of, 165.
—— water at, 22.
Carpenter, Dr., on the Croydon and Beddington sewaged lands, 347.
Carpet works, liquid refuse from, 255.
Carriers for sewage, 310, 325.
Catch-water system of irrigation, 314.
Cellar population of Liverpool, health of, 53, 178.
Cement and tarred gaskin as a jointing material for sewer pipes, 65, 191
Centrifugal pumps, 135, 139.
Cesspit privies and cesspools, 60, 150, 217, 225, 226, 247.
Cesspools in or near dwellings, 150, 226.
—— objections to, 60, 218, 225, 226.
Chalk, cost of well-sinking in, 115 to 117.
—— quality of water from, 32, 112.
—— reduction of water level in, 37, 112; Appendix F.
—— yield of water from, 115, 116.
Chandler's ball valve, 242.
—— water-waste preventer, 89.
Charcoal as a deodorizer of sewer gas, 214.
—— in sewer ventilators, 214, 247.
Charge for water supply in different towns, 22.
—— in villages, 109, 246.
Chaumont, Dr. de, as to water and carbon given off by an adult per diem, 2.
—— experiments of, to ascertain the difference between external and internal air, 5.
—— on the effect of ozone, 7.
—— researches of in sanitary science, 355.
Cheltenham, increase of population at, 166.
Cheltenham, reduction of phthisis by drainage of subsoil at, 49.
—— rent paid for sewage at, 258.
Chemical precipitation of sewage, 59, 178, 180, 271, 352.
—— cost of, compared with land treatment, 261, 278.
—— objections to in Thames and Lee valleys, 279, 280.
Chemical works, liquid refuse from, 168.
Chemists' value of liquid sewage, 256, 306.
Chester, water at, 22.
Chiswick, average monthly rainfall at, 23.
Choke-damp, 1.
Cholera, propagation of, by impure water, 35.
Christison, Dr., on the sanitary condition of district near Edinburgh sewaged lands, 345.
Cinder-sifting ash closet, 100, 223.
Circular and egg-shaped sewers compared, 188.
Cisterns, water, 142.
—— for water-closets, 86 to 90, 143.
Civita Vecchia, air of marshes near, 11.
Clarke's gully, 209.
—— Dr., process for softening hard water, 45, 112; Appendix G.
Clay joints for pipe sewers, 65, 191, 247.
—— soils for irrigation and intermittent filtration, 302, 321.
—— London, water capacity of, 53.
—— Oxford, water capacity of, 53.
Clays, underdrainage of, 55.
—— water from the underdrainage of, 53.
Closet, water (see Water-Closets).
Closets, dry, 98, 222.
—— soils suitable for, 222.
—— value of manure from, 103, 269.
Clutterbuck, Rev. J. C., on the reduction of water level in chalk, 37, 112.
Coal formation, water from, 118.
Cobbold, Dr., examination for entozoa in sewage produce, 349.
Cobham, average monthly rainfall at, 23.
Coghlan, Mr., C.E., on charcoal in sewer ventilators, 214.
Combined works for crowded valleys, 343.
Common sewers, limit of distance from dwellings, 175.
Communicating sewers (private), 58, 65, 174.
Concrete floors, necessity of, 56, 150.
—— sewers, 194.
—— strength of blocks of, 194.
Constant service of water compared with intermittent service, 230.

Constant service of water, importance of, 227.
Construction of wells, 123,
Consumption, effect of damp soil on development of, 14, 49.
Copper and brass works, liquid refuse from, 168, 255.
Cost of scavenging in various towns, 224; Appendix I.
—— well sinking, 114 to 117.
Cotton mills, liquid refuse from, 255.
Country houses, remarks on sanitary condition of, 151.
Country mansions, legal obligations as to, and means of disposing of liquid refuse, 58 to 65; Appendix H.
Coventry, sulphate of alumina process at, 282.
—— value of sludge at, 269.
Cowls for ventilation, 70, 108.
Cows fed on sewage produce at Edinburgh, health of, 350.
Cresswell, Dr., sanitary condition of district near Norwood sewaged lands, 346.
Crookes, Mr., native guano process, 279.
Crops, maxima, from sewage farms, 259.
—— suitable for sewage farms, 261, 262.
Croydon, reduction of death-rate from phthisis by drainage of subsoil, 49.
—— sanitary condition of district near sewage farm at, 347.
—— sewage farm, effect of frost on sewage at, 298.
Cultivated surfaces, filtration of water from, 44, 127.
—— quality of water to be obtained from, 31, 33.

Damp-courses, necessity of, 56.
Danchell filter, 145.
Darlington, water at, 22.
Deacon's, Mr., C.E., waste detection meter, 232; Appendix N.
—— manholes, 200.
Deane's stench and grease trap, 93.
Death-rate of healthy districts, 178
Deep wells, definition of, 109.
—— in chalk, 37, 112, 115 to 117.
—— in new red sandstone, 36, 111, 113 to 117.
—— objections to, 118.
—— quality of water from, 31, 33, 34.
Delivering, sewage, conduits, 310, 325.
Depth of subsoil drains in towns and villages, 175.
Derby, increase of population at, 166.
Detritus, road, 159, 265.
Dickenson, the late Mr., experiments of, to ascertain the infiltration of rain through chalk, 25.
Dines, Mr. G., rainfall in metropolis, 23.
Discharge of sewers laid at different inclinations, 67, 186
—— actual and calculated, 188.
—— variation of, at certain periods of the day, 169.
Disposal of sewage—crowded valleys, 343.
———— inland towns, 180.
———— isolated dwellings, 58 to 65; Appendix H.
———— seaboard towns, 177.
———— tidal river towns, 178.
———— villages and hamlets, 182.
—— on land, money results of, 260.
—— proportion of expenditure to be charged to sewerage system, 258.
—— to be charged against land utilised, 258.
Distribution of sewage on land, modes of, 314, 324.
Docwra, Mr., on the sinking of wells, 116.
Domestic filtration, 143.
Doncaster sewage farm, 257.
—— sludge disposal at, 267.
Douglas' hydraulic ram, 133.
Doulton's capped pipes, 193.
—— gully traps, 95, 207, 210.
—— sluice chambers, 311, 312.
—— stoneware sewage carriers, 311.
Dover, subsoil water entering sewers of, 164.
Drain, definition of, 50.
Drain-sewer, 51, 52.
Drainage of site of dwelling, necessity of, 11 to 18, 49 to 55, 163.
—— influence on temperature, 17, 18.
—— method of, 55.
Drainage of soil for irrigation and intermittent filtration, 61, 301, 308, 322.
Drained soil, cleansing power of, 16.
Drains in contradistinction to sewers, 16, 49, 162.
—— in free and stiff soils, discharge of water from, 53.
Drains under dwellings and near trees, 55.
Dripping roofs, 56.
Dry closets, 98, 222.
—— manure, value of, 102, 269.
—— soils suitable for, 222.
Dry rot, 57.
Duncan, Mr., rainfall evaporated from pervious and impervious surfaces, 29.
—— Dr., wet soils, their effect on health, 53.
Dust bins, 99, 226, 227.
Dwelling, the, certificates of sanitary condition, 149.

Dwelling, Division III.:
—— Sec. XLII. Definition of the term "the dwelling," 48.
—— XLIII. Of the site, 48.
—— XLIV. Drainage (in contradistinction to "sewerage") essential to a healthy site, 49
—— XLV. Definitions of the terms "drain" and "sewer," 50.
—— XLVI. Of the capacities of different soils for the retention of water, 52
—— XLVII. Capillary attraction and evaporation, 54
—— XLVIII. Mode of underdrainage required to dry the sites of dwellings, 55
—— XLIX. Concrete floors and areas essential to healthy basements, 56
—— L. Dripping roofs, 56
—— LI. Definition of sewage, 57.
—— LII. The mode of disposing of the liquid refuse to be determined before laying out external sewers, 58.
—— LIII. On present legal obligations in relation to liquid refuse from isolated dwellings, 58
—— LIV. Mechanical deposition and chemical precipitation inapplicable, 59
—— LV. The modes of treating sewage available for isolated dwellings, 60
—— LVI. Means of collecting the liquid refuse and of regulating its distribution, 63.
—— LVII. Reasons why sub-irrigation may be dangerous, 64.
—— LVIII. External sewerage, 65.
—— LIX. Ventilation and flushing of the external sewers, 70.
—— LX. Water-closets and their appliances, 71.
—— LXI. Sinks and their appliances, 91.
—— LXII. Scavenging and external dry closets, 99.
—— LXIII. The ventilation of the dwelling, 103.
—— LXIV. The water supply of the dwelling, 108.
(1) Wells, 109.
Dwelling, Division III.:
(2) Rain water from roofs, &c., 125.
(3) Surface water and under drainage water, 126.
—— LXV. Of different motive powers to raise water, 127.
(1) Manual, 130.
(2) Horse, 131.
(3) Wind, 132.
(4) Water, 133.
(5) Steam, 135.
—— LXVI. Pumps, 136.
—— LXVII. Underground tanks for the storage of water, 141.
—— LXVIII. Cisterns for the inner service of the dwelling, 142.
—— LXIX. Domestic filtration, 143.
—— LXX. Concluding remarks on the sanitation of the dwelling, 148.
Dye works, liquid refuse from, 167, 255.
—— purification of liquid refuse from, 335.
Dyke, Mr. T. J., Merthyr filtration areas, 330.

Earth closets, 99, 222, 225.
—— value of manure from, 103, 257.
Eassie, Mr., temperature of rooms, 107.
Eastwick (Leatherhead), sewage disposal work at, 63, 183; Appendix H.
Eaton Hall, Chester, well in new red sandstone at, 114.
Edgware, well at, 116.
Edinburgh, health of cows fed on sewage produce at, 350
—— sanitary condition of district near the sewaged lands at, 345, 348.
Egg-shaped and circular sewers, 188.
Ely, reduction of death-rate by drainage of subsoil at, 49.
Engineer, duty of, in relation to air, 13.
—— the dwelling, 148.
—— the town and village, 153.
—— water, 35 to 45.
Entozoa in animals fed on sewage produce, 349.
Epsom sewage farm, 258.
Eton sewage farm, 306
Evaporation and capillary attraction, 28, 29, 54.
—— effect of on temperature, 17.
—— reduction of by drainage, 17.
Exeter, average monthly rainfall a
—— water supply of, 22.
Exposure to impure air, effect of, 18.

External sewers (private) of dwellings, 58, 65, 174.
Eytelwein's formula for calculating the discharge of circular culverts, 187.

Farming, sewage, made profitable by combination with intermittent filtration, 339, 352.
—— profitless as now conducted, 259, 262, 339.
Farms, sewage, rents paid for, 257.
Farr, Dr., researches in sanitary science, 355.
Fens, improvement of by drainage, 16.
Fenton, Dr., effect of damp soil in promoting phthisis, 14.
Ferrule, the "pea" or "pin," for water pipes, 228. [35.
Fever, propagation of by impure water,
—— resulting from impure air, 18.
Field's, Mr. Rogers, flush tank, 69, 71, 91.
—— sub-irrigation drains, 64.
Filtration of water, domestic, 40, 143, 150.
—— from roofs, 40.
—— from underdrains and cultivated surfaces, 43, 126.
—— insufficiency of as a safeguard, 35.
Filters, 40, 144.
Flannel mill, refuse liquid from, 168, 255.
Flaps for sewers and sewer junctions, 69, 176, 211, 212, 213.
Fleck, Professor, on ground air, 8.
Flooding land with sewage condemned, 301.
Flood's manhole cover, 200.
—— sewer flap, 212.
Flower, Captain, on Hille's sewage process, 289.
Flushing of sewers, 69, 150, 201, 247.
—— gate for sewers, 202.
—— gully, self-acting, 203, 209.
Formulæ for calculating the discharge of culverts, 186, 187.
—— strength of iron pipes, 195.
Fox, Dr., on ozone, 7.
Frankland, Dr. E., analyses of effluents from Merthyr filtration areas, by, 329.
—— explanation of intermittent filtration by, 318.
—— experiments of, on the intermittent filtration of sewage through natural soil, 61.
—— method of to ascertain the quality of water, Appendix D.
—— on the value and nature of sewage, 252.
—— on water supply, 34.
—— researches in sanitary science, 355.
Free soils, irrigation upon, 304.
Free soils, intermittent filtration through, 321.
Frost, effect on sewage, 299.

Galton, Captain Douglas, C.B., on sewer velocities, 185.
Galvanising works, liquid refuse from, 255.
—— injurious nature of, 168.
Garden allotments, disposal of village sewage on, 183, 352.
Gases from common sewers, means of excluding, 69, 207, 212.
General Sewage Manure Company, 269, 281.
Gennevilliers, Paris, sewage farm at, 267, 316.
Geological formation, influence on quality of water, 20.
German silver works, injurious nature of liquid refuse from, 168, 255.
Gibson's dry closet, 100.
Gilbert, Dr., value of earth closet manure, 102.
—— value of sewage, 254, 256.
Glasgow, hourly gaugings of the discharge of sewers of, 170.
—— subsoil water in sewers of, 164.
Gloucester, water supply of, 22.
Gorhambury house, water supply of, 132.
Goux dry system 221, 269.
Grant, Mr., use of concrete for sewers, 194.
Grease, interception of, from sewers, 68, 91, 95, 150.
—— and trap tanks, 68, 91.
Great Marlow, well in chalk at, 116.
Greaves, Mr. C., on the absorption of rain by soil, 26.
Greenwich, rainfall at, 23.
Ground air, 7.
Guest and Chrime's ball valves, 240, 243.
—— meter, 233.
—— screw tap, 236.
—— water-waste preventer, 89.
Guildford, well in chalk at, 116.
Gullies and trap tanks, 91, 175, 206.
Gywnne's centrifugal pumping engine, 136, 139.
—— reciprocating double-acting pump, 134.
—— tube well, 123.
—— turbine and centrifugal pump, 135.

Halifax, Goux absorbent pail system at, 221, 269.
Hanson's sewage process, 277, 290.
Hard and soft waters, 45, 46, 112, and Appendix G.

Harrison, Mr. J. Thornhill, proportion of rainfall discharged by Thames, 29, 30.
Harrogate, sewage irrigation at, 303.
Haviland, Dr., Goux system of excrement disposal, 221.
—— promotion of phthisis by damp soil, 14.
Hawksley, Mr. T., C.E., egg-shaped sewer, 189.
—— rainfall at Redmires, 24; and Appendix E.
—— sewer velocities, 185.
Haywood, Mr. W., C.E., temperature of London sewers, 297.
Health, influence of wet subsoil upon, 11 to 16, 18, 48 to 55.
—— of cows fed on sewage produce, 349, 350.
—— of localities surrounding sewaged lands, 344.
Heat, effect of, in promoting malaria, 11.
—— required to raise water from freezing to boiling point, 104.
Heathcote Farm, Leamington, sewage irrigation at, 305.
—— treatment of sludge on land at, 267.
Heating of dwellings, data for the, 104.
Hemans, the late Mr. J. W., C.E., evaporation from impervious and pervious surfaces, 29.
Hendon, well in chalk at, 116.
Henley-on-Thames, well in chalk at, 116.
Herschel, Professor, on evaporation from wet substances, 17.
Hertford, chemical treatment of sewage at, 280.
Hewson's, Mr. T., C.E., storm overflow arrangement, 211.
High Wycombe, well in chalk at, 116.
Hille's sewage process, 289. [53.
Hinxworth, drainage experiments at, 17,
Hitchin, clay jointing faulty at, 192.
—— lime process discarded at, 291.
Hofmann, Dr., effect of impure water on animal economy, 20; Appendix C.
—— value of sewage, 256.
Holden's sewage process, 290.
Hope, Mr. W., V.C., Bretons Farm, 258.
Hopper closet, 73.
Horse and manual power, data for calculating, 128, 129.
—— power for raising water, 131.
Howarth's archimedian screw ventilator, 108.
Huddersfield, water supply at, 22.
Huxley, Professor, air inhaled and carbonic acid produced by individuals, 2.

Impervious soils, rainfall thrown off and available for storage, 29, 125.
Impervious soils, rainfall evaporated from, 28.
—— surfaces and roofs, water to be obtained from, 125.
Impure air, effect of exposure to, 18.
—— measured by carbonic acid, 12.
Inclinations necessary for certain velocities in sewers, 186.
—— and velocities for private communicating sewers, 66, 67.
Increase of population in different towns, 166.
Inland towns, disposal of sewage from, 180, 351.
Intercepting and outfall sewers, 176, 183.
Intermittent filtration of sewage, 61, 182, 249, 260, 264, 296, 299, 318, 339, 343, 351, 352.
—— combined with irrigation, 339, 352.
—— contrasted with irrigation, 320.
—— Kendal works of, 260, 264, 330, 336.
—— measures to secure permanency of effect in, 319, 334.
—— Merthyr works of, 326.
—— opinion of Baron Liebig on, 62, 336.
—— purity of effluent sewage water after treatment by, 329.
—— quantity of land required for, 61, 62, 251, 319, 351, 352.
—— return from, 260, 325, 328.
—— soils, suitable and unsuitable for, 321.
—— surface preparation for, 324.
—— tanks, carriers, &c., for, 325.
—— trade refuse, purification of, by, 62, 334.
—— underdrainage of soil for, 322.
—— of water, 40, 144.
Irrigation, 61, 182, 249, 260, 264, 299, 300, 339, 351, 352, 353.
—— combined with intermittent filtration, 339, 352.
—— contrasted with intermittent filtration, 320.
—— Eton, 306.
—— flooding lands by sewage, 301, 304.
—— Harrogate, 303.
—— Heathcote Farm, 257, 305.
—— Lodge Farm (Barking), 267, 304, 309, 346.
—— modes of distributing sewage by, 314.
—— quantity of land to be acquired or, 250, 262, 351.
—— soils, suitable and unsuitable for, 301.
—— surface preparation for, 308.
—— tanks, carriers, &c., for, 310.
—— technical meaning of, 300, 320.
—— underdrainage of soil for, 308.

Iron pipes, 195.
Isolated dwellings, legal obligations as to liquid refuse from, 58.
—— sewage disposal for, 58, 60, 63; Appendix H.
Italy, miasma of, 10.

Jacob's, Mr. A., C.E., gully, 209.
Jenning's sink trap, 98.
—— water-closet, 78.
Jointing materials for pipe sewers, 65, 191, 247.
Jones, Mr. C., C.E., charcoal in sewer ventilators, 214.
Jones, Lieutenant-Colonel, Wrexham sewage farm, 258, 260.
Jones, Mr. W., on Merthyr filtration areas, 330.
Junction of private and common sewers, 66, 174.

Keates, Mr., native guano sewage process, 275.
Kendal, intermittent filtration at, 260, 264, 330, 336.
—— Messrs. Rawlinson and Read's remarks on sewage works at, 264, 331.
—— money results of sewage disposal at, 260.
—— water supply of, 22.
Keswick, rainfall at, 23.
King's dry closet, 101.
King's Langley, absorption of rain by chalk at, 25.
Knight, Dr. Sladen, on the effect of dry and wet soils on health, 14.

Lampholes, 173, 199.
Lancaster, rainfall at, 23.
Land, advantage of resorting to, for sewage disposal, 249, 295, 299.
—— application of sewage to, 61, 248, 258, 295, 299, 300.
—— compared with chemical treatment of sewage, 261, 278.
—— deposit of sewage sludge on, 267, 295.
—— money results of applying sewage to, 260.
—— preparation of, for irrigation, 308, 353.
—— for intermittent filtration, 324, 353.
—— underdrainage of, for sewage irrigation, 308. [322.
—— for intermittent filtration, 61, 308,
Landau's automatic ventilating cowl, 108.
Latham, Mr. B., egg-shaped sewers, 188.
—— storm overflow arrangement, 211.
Lawes and Gilbert on water-closet sewage, 254, 256.
Lea Hall, Cheshire, water supply of, 133.
Leaky sewers, dangers of, 13, 15, 51, 65, 150, 163, 164, 178, 182, 191, 192, 226, 247.
Leamington, increase of population at, 166.
—— native guano sewage process at, 273.
—— outflow of sewers at, 170.
—— sewage, rent paid for, 257, 305.
Lee, objections to chemical treatment of sewage in the valley of the, 280.
—— river, as a source of potable water, 35, 44.
Leeds, cost of chemical treatment of sewage at, 261, 278.
—— Hanson's sewage process at, 278, 291.
—— native guano process at, 276.
—— value of manure from sewage of, 269
—— water supply of, 22.
Leicester, lime process at, 291.
—— native guano process at, 273.
—— reduction of deaths from phthisis by drainage of subsoil at, 49.
—— subsoil water in sewers of, 164.
—— water supply of, 22
Lemon, Mr. J., C.E., charcoal in sewer ventilators, 214.
—— manhole arrangements; Drawing X.
Liebig, the late Baron, on intermittent filtration, 62, 336.
—— on the value of sewage, 251.
Liernur's pneumatic sewerage system, 293.
Lift and force pumps, 137.
Ligertwood, Dr., on the sanitary condition of localities near Edinburgh sewaged lands, 345.
Lime process of sewage treatment, 269, 291.
—— softening water, 45, 112; Appendix G.
Lincoln, water supply of, 22
Linen mill, purification of liquid refuse from, 336.
Littlejohn, Dr., on the health of cows fed on sewage produce, 350.
—— on the sanitary condition of locality near Edinburgh sewaged lands, 348.
Liverpool, death-rate of, 178.
—— health of cellar population of, 53, 178.
—— increase of population at, 166.
—— lowering of water level under, 36, 112; Appendix F.
—— subsoil water in sewers of, 164.
Loans, table showing annual sums required to repay with interest, 356.
Lodge Farm, Barking, sanitary condition of, 346.
—— sewage irrigation at, 304.

Lodge Farm, surface slopes at, 309.
—— treatment of sludge at, 267.
London, air of, 3, 4.
—— air of sewers of, 10.
—— lowering of water level under, 37 112; Drawing L, Appendix.
—— monthly rainfall in, 24.
—— outflow of sewers, hourly, 170.
—— surface waters, 155.
—— temperature of sewers of, 297.
—— water supply of, 22.
London School Board, air space required by, in schools, 106.
Lovegrove's street gully, 209.
Lowe's gully, 208.
Lucas, Mr. J., horizontal wells, 125.
Lund, Mr., subsoil water entering sewers of Bedford, 165.

Macclesfield, reduction of phthisis by drainage of subsoil at, 49.
—— well in new red sandstone at, 113
Machinery for raising water from wells, 130.
"M. and C." process of sewage treatment, 269.
Malaria, 10, 11, 13.
Manchester, air of, 4.
—— prevention of water waste in, 232
—— rainfall at, 23.
—— water fittings at, 232; Appendix K.
—— well in new red sandstone at, 113.
Manholes, 172, 199.
—— covers, 200.
Mansergh's trap, 92.
Manual power and machinery suitable for raising water from wells, 130.
Manure from dry closets, value of, 102, 269.
—— from sewage sludge, value of, 269.
Map of drains and sewers, necessity of, 176.
Marlow, Great, well in chalk at, 116.
Marshall, Mr. W., on the partial recurrence of ague in fens, 16.
Marsh gas in sewers, 10.
—— in soils saturated with sewage, 8.
Marshes of Italy, air of, 10
Marshy places in Scotland, air of, 3.
Materials for sewers, 190.
Mather and Platt's boring machinery, 113.
Mechanical deposition of sewage, 59, 265, 271.
Mercer's Hill Brewery (Uxbridge), well at, 115.
Merthyr, crops grown on filtration areas at, 324, 328.
—— effluent water from filtration areas at, 127, 329.
Merthyr, intermittent filtration areas at, 326.
—— Messrs. Rawlinson and Read's report on sewage works at, 329.
—— outflow of sewers, hourly, 170.
—— reasons for adoption of intermittent filtration at, 319.
—— reduction of phthisis by drainage of subsoil at, 49.
—— sewage-grown vegetables, use of, at, 349.
—— temperature of sewage and effluent sewage water at, 298.
Meter, Mr. Deacon's, for detection of waste of water, 232; Appendix N.
Meters for private houses, 233.
Metropolis, monthly rainfall in, 24.
—— Water Act, regulations under, 232; Appendix M.
Metropolitan Lodging Houses Act, air space required by, 106.
Miasma, nature of, 10.
Middens, 99, 218, 225.
—— and privies, pollution of wells by, 35, 45, 60, 110, 219, 227, 247.
—— and water-closet towns, sewage of compared, 252.
Middlesbrough, increase of population at, 166.
Milburn's sludge filter, 283.
Mines, injurious character of liquid refuse from, 168.
Minimetric method of analysing air, 12; Appendix A.
Mohair and alpaca works, purification of liquid refuse from, 335.
Molesworth's formula for strength of iron pipes, 196. [209.
Morant, Mr., C.E., on Alexander's gully,
Morgan, Mr. H. J., on slopes suitable for irrigation, 309.
Morley, Mr., on subsoil water admitted to sewers of Carlisle, 165.
Morrell's dry closet, 100.
Mortar for brick sewers, 190.
Morton, Mr. J. C., on catch-water system of irrigation, 314.
—— on Heathcote Farm, 305.
Moser's dry closet, 102.
Motive power for raising water from wells, 127.
Munich, air of, 5.
Murray's, Mr., C.E., table showing actual and calculated discharge of sewers, 188.

Nash Mills, Herts, rainfall and percolation through soil at, 26.
Native Guano Company's process, 272.
—— value of manure, 269.

Newark, Abyssinian tube well at, 123.
Newport (Mon.) reduction of death-rate by drainage of subsoil at, 15, 49.
—— increase of population at, 166.
New red sandstone, cost of well sinking in, 114, 116, 117.
—— failure to find water in, 113.
—— lowering of water level in, 36, 112; Appendix E.
—— quality of water from, 31, 112.
—— yield of borings in, 113.
Newton's street gully, 209.
Nichols, Professor (U.S.A.), experiments of, to ascertain the air of soils, 8.
Night-soil manures, fertilising and commercial value of, 268.
Nitrogen in common air, 1. [8.
—— in air of soils saturated with sewage,
—— in air of sewers, 10.
Northampton, water supply of, 117.
North of England, winter and summer rainfall in, 25.
Northfleet, Abyssinian tube well at, 123.
Norwich, prevention of water waste at, 232; Appendix J.
—— rainfall at, 23.
Norwood, sanitary condition of district near sewaged lands at, 346.
Nottingham, outflow of sewers of, hourly, 170.
—— pail system at, 221; Appendix I.

Old red sandstone as a source of water, 36, 112.
Oolitic strata, quality of water from, 117.
Open spaces, air of, 4.
Organic matters polluting air, 6.
—— in soils, effect of decomposition on air, 8.
—— power of soils to purify, 7.
Outfall, classification of towns and villages according to, 177.
Outlet valves, 210
Overcrowding of dwellings, 247.
Overflows for storm waters, 210. [13.
Oxidation resulting from drainage of soil,
Oxygen in common air, 1, 2, 3.
—— soils saturated with sewage, 8.
—— water, 19.
—— weight and description of, 1.
Ozone, 7.

Pæstum, air of marshes near, 11.
Pail-closet system, 99, 218, 220, 225; Appendix I.
Palmerston, the late Lord, improvement of temperature by drainage of soil, 18.
—— on sub-irrigation, 65.
Pane and gutter system of sewage distribution, 315.
Paper mill, liquid refuse from, 167, 255.
Paris, air of sewers in, 10.
—— road detritus discharged into Seine from sewers of, 161.
—— sewage farm at Gennevilliers, 267, 316.
—— sulphate of alumina process at, 284.
Parkes, the late Dr. E. A., air of barracks and hospitals, 5.
—— air required in dwelling to counteract vitiation, 106.
—— carbonic acid given off by an adult man, 2.
—— increase of temperature by drainage, 17.
—— marsh gas in sewers, 10.
—— researches of, in sanitary science, 355.
—— water required by an adult, 21.
—— the late Mr. Josiah, evaporation of water from soil, 17.
Parker's dry closet, 100.
Patricroft, well at, 113.
Paul, Dr. B. H., analysis of effluent sewage water from Merthyr filtration beds, 329.
—— report on roof water, 41.
"Pea" or "pin" ferrule, 228.
Penstocks, 201.
Peters and Donald's water-closet and water waste preventer, 76.
Pettenkofer, Professor, method of analysing air, 13; Appendix B.
—— quantity of nitrogenous matter escaping from leaky sewers, 164.
—— rise and fall of ground water, effects of, 49.
—— standard of impure air, 12.
Phillips, Mr. J., on sewer velocities, 185.
Phosphate Sewage Company's process, 279.
Phthisis, effects of damp soil on, 14, 15, 49, 53.
Pipes, iron, for sewers, 195 to 198, 199.
—— formulæ for calculating strength of, 195, 196.
—— stone and earthenware, thickness of, 191.
———— Doulton's capped, 193.
———— insufficiency of clay joints for, 191. [247.
———— jointing material for, 65, 191,
———— Stanford's patent, 193.
Plymouth, water supply of, 22. [7.
Pollution of air, agencies counteracting,
—— of air by damp soil, 13 to 16, 18, 48 to 55.
—— of shallow wells, 45, 219.
—— of water, 19, 60,

Poncelet's formula for discharge of culverts, 187.
Population, increase of in different towns, 166.
—— sewage due to, 165.
Potts' Edinburgh sewer trap, 72.
Precipitation of sewage, chemical, 59, 178, 180, 271, 352.
—— mechanical, 59, 265, 271.
Preparation of land for intermittent filtration, 324, 353.
—— irrigation, 308, 353.
Preston, increase of population at, 166.
Pritchard, Mr., C.E., on charcoal in sewer ventilators, 214.
Privies and cesspools, 60, 150, 217, 225, 226, 247.
—— pollution of wells by, 219.
—— prohibition of, in towns, 219.
Prony's formula for discharge of culverts, 187.
Public Health Act, 1875, 50, 51, 58, 59, 175, 246.
Pumps, 119, 123, 129, 136.

Radcliffe, Mr. Netten, dry-closet system, 225.
—— Eastwick sewage work; Appendix H.
—— researches of, in sanitary science, 355.
Rain, evaporation of, from absorbent and non-absorbent soils, 28.
—— quantity absorbed by soils, 25.
—— thrown off absorbent and non-absorbent surfaces, 29.
—— water, effect of filtration of, 39, 41, 125.
—— water, quality of, when collected on roofs, &c., 30, 33, 41.
—— water pipes, objectionable as sewer ventilators, 70.
Rainfall, average, in winter and summer, 25.
—— depth converted into tons, cubic feet, and gallons, 158.
—— effect upon wells of medium depth, 110.
—— proportion required as water supply, 23.
—— yearly and monthly in different districts and countries, 22; Appendix E.
Ram, the hydraulic, 133.
Rankine, Dr., increase of temperature by drainage of soil, 17.
Rate for water in country districts, 109, 246.
—— in towns, 22.
Rath's, Herr Von, sugar manufactory in Silesia, purification of liquid refuse at, 62, 336.
Rawlinson, Mr. R., C.B., advancement of sanitary science by, 355.
—— manhole arrangement of, 201.
—— "suggestions" upon sewerage and drainage, 52, 173.
—— and Read's report, 263, 268, 329, 330, 331, 334, 341.
Rawson, Mr. C., native guano sewage process, 272.
Redhill trap, 95.
Redmires (Sheffield) rainfall at, 24; Appendix E.
Regulations under Metropolis Water Act, 232; Appendix M.
Regulator, the self-acting sewage, 63, 183, 339, and Appendix H.
Reservoir-sewers, 157, 184.
Richardson on the heating and ventilation of dwellings, 104.
River conservancies for sanitary purposes, 343.
—— crossings (sewers), 195, 198, 199.
—— waters contaminated with sewage not cleansed by lengthened flow, 35.
Rivers and streams, preservation of, from pollution, 351.
—— as a source of domestic water supply, 33, 44.
Rivers Pollution Commissioners, classification of hard and soft waters by, 46.
—— constant service of water, 229, 230.
—— definition of "sewage," 57.
—— effect of frozen condition of soil upon sewage disposal, 298.
—— insufficiency of filtration as a safeguard against polluted water, 35.
—— native guano sewage process, 273.
—— propagation of disease by contaminated water, 35.
—— purification of trade liquid refuse, 334.
—— results of analyses and remarks on quality of waters from different sources, 30 to 47, 108 to 118, 125 to 127.
—— sanitary condition of localities near sewaged lands, 344.
—— sewage of midden and water-closet towns, 253.
—— standards of purity of effluent sewage, 181, 255.
—— Thames and Lee, as sources of water supply, 35
Rivers Pollution Prevention Act, 59, 180.
Road detritus, 159, 206, 353.
—— necessity for interception from sewers, 160, 206.

Rochdale, pail system at, 220; Appendix I.
—— value of manure collected by pail system at, 269.
Rochester, death-rate of wet and dry portions compared, 14.
Rome, rainfall at, 22. [258.
Romford, rent paid for sewage farm at,
Roofs, evils of dripping, 56.
—— rain water from, 30, 33, 34, 39, 125.
Roscoe, Professor, 6.
Rotherham, increase of population at, 166.
Rothschild, Sir A. de, dry earth system on estate of, 222.
Rugby, reduction of phthisis by drainage of soil at, 49.
—— sewage of, 254.
Rules to be observed in the sanitation of the dwelling, 148.
—— in sewage disposal, 351.
—— in the sewerage of towns and villages, 171, 246.
Russell, Dr., analysis of effluent sewage from Merthyr filtration areas by, 329.
—— experiments of, to ascertain the temperature of rooms, 107. [304.
Rye-grass as a sewage crop, 259, 261, 262,

Salford, cinder-sifting ash-closet system at, 223.
Salisbury, drainage of subsoil, effect of, at, 15, 49, 165.
—— water supply of, 22.
Sanitary appliances, 71, 149, 199, 235.
—— arrangements of dwellings, necessity of control over, by local authority, 247.
—— condition of country houses, 151.
—— condition of localities in proximity to sewaged lands, 344.
Sanitation of dwellings, rules to be observed, 148.
—— towns and villages, rules to be observed, 171, 246.
Saturated wet soils, effect of, on health, 11 to 16, 18, 48 to 55.
Scavenging and dry closets, 98, 217, 247.
Schubler, Professor, effect of drainage on temperature, 17.
Scotland, air on heaths and low marshy places of, 2, 3.
Scott's, General, C.B., sludge process, 292.
Screw taps, 236.
Seaboard towns, disposal of sewage from, 177.
Seaton, Dr., effects of damp soil in promoting phthisis, 14.
Self-acting flushing gully, 203, 209.
—— sewage regulator, 63, 183, 339; Appendix H.
Self-supplying oxidising filter, 40, 144.
Sewage, application to land, 61, 248, 258, 295, 299, 300.
—— chemical treatment of, 59, 178, 180, 271.
—— committee of British Association, 103, 285, 286, 298, 303.
—— cost of chemical treatment of, 261, 278.
—— definition of, 57.
—— disposal of, pecuniary effect upon ratepayers, 260, 261.
—— extent of land required for cleansing and utilising, 61, 250, 301, 318, 320.
—— farming, drawbacks attending, 261, 340.
—— farms, crops suitable for, 261, 262.
—— farms, rent paid for, 257.
—— land the deodoriser, cleanser, and utiliser of, 249, 299.
—— mechanical subsidence of, 271.
—— of closet and midden towns, 252.
—— sludge, 160, 265 to 270.
—— solid matters contained in, 265.
—— temperature of, 297, 298.
—— trade refuse mixed with, 167, 254, 336.
—— treatment and disposal of, Division V.:
—— Sec. XC. Prefatory observations on sewage disposal, 248.
—— XCI. Character of sewage discharged from towns of different characters, 251.
—— XCII. The value of sewage, 256.
—— XCIII. The solid matters contained in sewage, 265.
—— XCIV. Of sludge, 266.
—— XCV. The clarification of liquid sewage by subsidence or chemical precipitation in tanks, 271.
(1) The A B C process, 272.
(2) Phosphate of alumina process, 279.
(3) Sulphate of alumina process, 281.
(4) Whitthread's process, 284.
(5) Weare and Company's process, 286
(6) Hille's process and other processes, 289.
(7) The burning of the combustible parts of sewage, 292.
(8) Liernur's system, 293.

Sewage, treatment and disposal of, Division V.:
—— XCVI. The advantage of retaining the sludge in the liquid sewage when applied to land, 295.
—— XCVII. Circumstances under which the special treatment of sludge may be necessary, 297. [age, 297.
—— XCVIII. The temperature of sew-
—— XCIX. Land the purifier of sewage and sewage the fertiliser of land, 299.
—— C. Wide surface irrigation, 300.
(1) Suitable and unsuitable soils, 302
(2) Underdrainage and surface preparation, 308.
(3) Delivering conduits, tanks, sluice chambers, carriers, and distributing channels, 310.
(4) The catch-water system of distribution, 314.
(5) The pane and gutter system of distribution, 315.
(6) The bed system of distribution, 315.
—— CI. Intermittent downward filtration, 318.
(1) Suitable and unsuitable soils, 321.
(2) Underdrainage, 322.
(3) Surface preparation and formation, 324.
(4) Delivering conduits, tanks, sluice chambers, carriers, and distributing channels, 325.
(5) The Merthyr works described, 326.
(6) The Kendal works described, 330.
(7) Cleansing of trade refuse, 334.
(8) General remarks on sewage disposal works, 337.
—— CII. Combination of intermittent filtration with irrigation essential to utilisation and purification, 339.
Sewage, treatment and disposal of, Division V.:
—— CIII. Combined works in crowded valleys, 343.
—— CIV. On the sanitary condition of localities near sewaged lands, 344.
—— CV. Concluding remarks, 351.
—— value of, 251 to 261.
Sewerage of dwelling, 57, 65, 150.
—— town or village, 153 to 177, 183 to 217, 246, 247.
Sewers acting as drains, 15, 49 to 52.
—— appliances used in, 199.
—— as reservoirs, 157, 184.
—— brick, 190. [188.
—— circular and egg-shaped, compared,
—— concrete, 194.
—— construction of and materials for, 190.
—— definition of term, 50.
—— deflected, 195.
—— earthenware or stoneware pipe, 65, 174, 191.
—— effect of admitting trade refuse into, 167, 254, 336.
—— flaps for, 69, 175, 211 to 213.
—— flushing of, 66, 69, 150, 185, 201, 247.
—— gas of, 10, 69.
—— inclinations and velocities for, 66, 185.
—— in unsound ground, 195.
—— iron pipe, 195.
—— jointing materials for pipe, 65, 191, 247.
—— junctions of, 66, 171, 199.
—— main outfall and intercepting, 176, 183.
—— map of, necessity for, 176.
—— proportionate sizes of main and tributary, 174.
—— sizes and velocities to render self-cleansing, 184.
—— sizes suitable for, of single dwellings, 67.
—— temperature of, 297.
—— ventilation of, 69, 150, 173, 201, 213, 247.
—— water-tight, necessity for, 13, 15, 51, 65, 150, 163, 164, 178, 182, 191, 192, 226, 247.
Shallow tube wells, 45, 119, 123.
—— wells, definition of, 109.
—— well waters, 31, 33, 35, 45, 219.
Sharpe's gully, 208.
Sheffield, increase of population at, 166.
—— rainfall at, 24; Appendix E.
Shrewsbury, water supply of, 22.
Silicated carbon filter, 146.

Silk print works, liquid refuse from, 255.
Simon, Mr. J., C. B., effects of damp soil in promoting phthisis, 14.
—— on dangerous character of privies, 218.
—— on dust-bins and ash-pits, 226.
—— on necessity of constant service of water, 229.
—— researches of in sanitary science, 355.
Simpson, Mr. J., C.E., as to sewer velocities, 185.
Sink appliances and disconnecting arrangements, 91, 150.
—— traps, 97.
Sinks, 68, 91, 150.
Sites of dwellings, 48, 55, 150.
Sludge, 160, 265 to 293, 295 to 297.
—— disposal of on land, 267, 295, 297.
—— value of, 266, 268 to 270, 273.
Sluice chambers, 312, 325.
Smith, Dr. Angus, deterioration of air, 1.
—— ground air, 7.
—— importance of small quantities of impurities in air when in excess of standard, 3.
—— minimetric method of analysing air, 12; Appendix A.
—— quality of air in different places, 3.
—— rain water from roofs, purification by filtration, 39, 125.
—— researches in sanitary science, 355.
Soap and alkali works, liquid refuse from, 255.
Soft and hard waters, 45, 46, 112, and Appendix G.
Softening of hard waters, Clarke's process for the, 45, and Appendix G.
Soils, capacity for retaining water, 52,
—— dry and wet, their effect on health, 11 to 16, 18, 48 to 55.
—— power of to oxidise organic substances, 7, 16, 249.
—— suitable and unsuitable soils for irrigation, 301, and intermittent filtration, 321.
Southampton, failure of deep well at, 37.
—— water supply of, 22.
Spongy iron filter, 145.
Spring waters, 32, 33, 34, 36.
Stand-pipes, 244.
Standard of attainable air, 1, 12.
—— pure water, 33.
—— Rivers Pollution Commissioners, 181, 255.
—— Thames Conservators for effluent sewage, 179.
Stanford's patent joint pipes, 193.
Steam power for the raising of water from deep wells, 135.
Stephenson, the late Mr. R., on sewer velocities, 185.
Stidder's gully, 210.
—— sink trap (Antill's), 98.
—— yard trap, 96.
Stiff's trap, 93.
Stockport, well in new red sandstone at, 113.
Stoke-upon-Trent, increase of population at, 166.
Stone's ball valves, 240, 241.
—— gullies, 208.
—— penstock, 205.
—— screw tap, 236.
—— stop-cock, 239.
—— waste preventing cistern, 87, 88.
Stop valves and taps for water pipes, 235.
Storm overflows and tidal or outlet valves, 210.
Strood, health of dry and wet portions compared, 14.
Subsoil drains in towns and villages, average depth of, 175.
—— water, effect on health, 11 to 16, 18, 48 to 55.
—— water, its admission into or exclusion from sewers, 162.
—— water, quantity discharged by sewers of different towns, 164.
Subterranean water supply, pollution of by soakage from cesspools, 60, 219.
Suction pump, 136.
Sunderland, air of sewers in, 10.
—— water supply of, 22.
Surface (cultivated) waters, quality of, 30, 31, 33, 34, 44, 126.
—— (uncultivated) waters, quality of, 30, 31, 33, 34, 38, 125.
Surface waters, their admission into or exclusion from sewers, 154, 247.
"Suspicious" waters, 33, 34, 39, 126.
Sutcliff's sink trap, 97.
Symons, Mr. J. G., average rainfall in England, 22.

Table showing average composition of unpolluted waters, 33.
—— average monthly rainfall in east and west of England, 23. [25.
—— average summer and winter rainfall,
—— carbonic acid in river mud, 9.
—— circumference and sectional area of circular and egg-shaped sewers, 189.
—— composition of midden and water-closet sewage, 253.
—— composition of trade refuse liquid, 255.
—— condition of air of sewers in different towns, 10.

Table showing crops (maxima) grown from sewage, 259.
—— discharges of sewers, actual and calculated, 188.
—— effect of rainfall upon wells of medium depth, 110.
—— extent of land benefited by sewage dressings of different quantities, 307.
—— increase of population in several towns, 166.
—— money results of applying sewage to land, 260.
—— power required to raise water from deep wells, 128.
—— proportions of cast-iron flange pipes, 198.
—— proportions of joints for cast-iron socket pipes, 198.
—— pump and power necessary to raise water from deep and shallow wells, 129. [292.
—— purification effected by lime process,
—— native guano process, 273, 275.
—— Weare and Company's process, 288.
—— Whitthread's process, 285.
—— quality of waters from various sources, 30.
—— quantity and quality of water used in different towns, 22.
—— quantity of land of different characters required for sewage, 323.
—— rainfall and percolation through soil, at Lee Bridge, 26, and at Nash Mills, Herts, 26.
—— rainfall converted into tons, cubic feet and gallons, 158.
—— repayment of loans with interest, 356.
—— size, depth, and cost of certain wells sunk in chalk, 116.
—— strength of concrete blocks, 194.
—— temperature of air, ground, sewage, and effluent sewage at Merthyr, 298
—— temperature of external air and sewer air, 298.
—— thickness, safe head and cost of iron pipes, 197.
—— variation in outflow from sewers, 170.
—— velocity and discharge of circular sewers laid at different inclinations, 67, 186.
—— water obtained from various wells in new red sandstone, 113.
—— water used in certain towns supplied on constant and intermittent systems, 230.
—— wettest months of year, 24.
Tangye's horizontal steam engine, 136.
Tanks and wells, motive power required to raise water from, 127.
—— for sewage, 271, 310, 326.
—— underground, for water, construction and cost, 141.
—— pollution of water in, 42.
Taps and stop valves for water pipes, 235.
Tarbotton, Mr. M. O., C.E., flushing arrangements adopted by, 202.
—— manhole arrangements adopted by, 201.
Tarred gaskin and cement for sewer joints, 65, 191.
Tatham, Mr. Alderman, sewage works, Leeds, 276, 290.
Taylor's, Mr. Alderman, pail system, 220. 269; Appendix I.
Telford's data for calculating manual and horse power, 128.
Temperature, improvement of by drainage of soil, 13, 17, 18.
—— of air in rooms, 107.
—— sewage, 297, 298.
—— sewage and effluent sewage water at Merthyr, 298.
—— sewers, 297, 298
Thames, rainfall and discharge by river compared, 29.
—— Rivers Pollution Commissioners on, as a source of domestic water supply, 35.
Thames Conservators, standard of, for effluent sewage, 179.
Thorburn, Mr. T. C., C.E., manhole arrangements of, 201.
Thudichum, Dr., value of sewage, 256.
Tidal or outlet valves, 210.
Tidal river towns, provisions of Rivers Pollution Prevention Act as to, 180.
—— treatment and disposal of sewage from, 178, 352.
Till, Mr. W. S., C.E., flushing arrangements adopted by, 202. [201.
—— manhole arrangements adopted by,
—— road detritus collected by sewers of Birmingham, 159.
Tilley's, Mr., experience in well-sinking in chalk and new red sandstone, 113 to 115.
Tomlinson, Mr. C., on warming and ventilating, 104.
Torquay, increase of population at, 166
—— subsoil water reaching sewers of, 164.
Town and village, Division IV.:
—— Sec. LXXI. General observations on the duties of the engineer in the sewerage of towns and villages, 153.

Town and Village, Division IV.:
—— Sec. LXXII. Surface waters, their admission into or exclusion from sewers, 154.
—— LXXIII. Road detritus, its influence on sewage disposal, 159.
—— LXXIV. Subsoil water, its admission into or exclusion from sewers, 162.
—— LXXV. Sewage due to:
(1) Population, 165.
(2) Local and special trades, 167.
(3) Water supply, 168.
—— LXXVI. The variation in discharge of sewage during the day — maximum and minimum, 169.
—— LXXVII. The liquid sewage to be removed by sewers distinguished from the solid refuse to be removed by the scavenger, 171.
—— LXXVIII. General arrangement of sewers or the system of sewerage, 171.
—— LXXIX. The mode of disposing of the sewage of towns and villages to be determined before fixing the main outfall or intercepting sewers, 176.
—— LXXX. On the classification of towns and villages, and the appropriate disposal of their sewage according to the nature of the outfall, 177.
(1) Seaboard towns, 177.
(2) Towns on tidal waters, 178.
(3). Inland towns, 180.
(4) Villages and hamlets — their special treatment, 182.
—— LXXXI. Main outfall and intercepting sewers, 183.
Town and Village, Division IV.:
—— LXXXII. Sizes and velocities required to render sewers self-cleansing, 185.
—— LXXXIII. Circular and egg-shaped sewers compared, 188.
—— LXXXIV. Construction and materials of sewers, 190.
(1) Brick sewers, 190.
(2) Pipe sewers, 191.
(3) Concrete sewers, 194.
(4) Iron pipes—river crossings and sewer deflections, 195.
—— LXXXV. Sewer appliances adopted by different engineers, 199.
(1) Manholes and lampholes, 199.
(2) Flushing arrangements and penstocks, 201.
(3) Gullies, 206.
(4) Storm overflows, and tidal or outlet valves, 210.
—— LXXXVI. Sewer ventilation, 213
—— LXXXVII. Scavenging of towns and villages, 217.
—— LXXXVIII. On water for towns and villages, with remarks on the constant system of supply, 227.
—— LXXXIX. Concluding remarks on the sanitation of towns and villages, 246.
Towns and villages, quantity of water necessary for the supply of, 22, 169.
—— rules to be observed in the sanitation of, 246.
—— subsoil drains in, depth of, 175.
Townend's, Messrs., mill, purification of liquid refuse from, 335.
Trade refuse, liquid, admission of into sewers, 167, 254, 334, 352.
—— composition of, 167, 255.
—— treatment of, on land, 62, 334.
—— when injurious to vegetation, 168, 255.
Trade water, quantity of, and charge for, in different towns 22.
Trades, polluting materials used in, 167.
Traps, outside, for dwellings, 68, 91.
—— sink, 68, 97.

Traps for water-closets, 68, 71,
Truro, average monthly rainfall at, 23.
Tube wells, 45, 119, 123
Tunbridge Wells, money results of sewage application at, 260.
Turbine, the, 134.
Typhoid fever, propagation of, by contaminated water, 35.
Tye and Andrew's sink trap, 97.
Tylor and Son's ball valves, 241, 243.
—— hydrant box, 245.
—— stand-pipe, 244.
—— trapping box, 90.
—— valve closet, 74.
—— waste-not cisterns, 86, 88. [81.
—— waste-not closet valves, 74, 79, 80,
—— waste-not screw tap, 237.
—— water meter, 234.

Uncultivated surfaces, waters from, 30, 31, 33, 34, 38, 125.
Underdrainage of land, &c., 11, 13 to 18, 48 to 56, 150, 163, 301, 308, 322.
Underdrainage water, 34, 43, 126, 127.
Underground rooms and cellars, precautions to be taken, 56, 150.
—— tanks for storage of water, 42, 141.
Underhay's ball valve, 242.
—— water-closet and regulator, 75, 82.
—— waste preventer, 83.
Unpolluted waters, average composition of, 33.
Upland (uncultivated) surface waters, 30, 31, 33, 34, 38, 125.

Valleys, crowded, disposal of sewage in, 343.
Value of land, increase in the, 249.
—— manure from dry and pail closets, 102, 269.
—— sewage, 251 to 261, 306.
—— sewage and night soil manures, 269.
—— sewage-sludge and sludge manures, 266, 268 to 270, 273.
Valve closets, 74.
Valves, tidal or outlet, 69, 210.
Vapour, watery, in air, 6.
—— congenial to health, 7.
—— exhaled from lungs, 2.
Variation in the discharge of sewers, 169.
Velocities and sizes to render sewers self-cleansing, 185.
—— bottom, 185.
—— data for calculating, 186, 187.
—— for private sewers, 67.
—— in sewers laid with different inclinations, 186.
Ventilation of dwellings, 103.
—— pipes of water-closets and urinals, 68, 71, 150.
Ventilation of sewers, 69, 150, 173, 201, 213, 247.
—— of sink pipes, 68, 150.
—— water-closets, 71.
Verulam's, Earl, pumping arrangements at Gorhambury, 132.
Villages and hamlets, disposal of sewage from, 182, 352; Appendix H.
—— and towns (see Town and Village).
—— depth of subsoil drains in, 175.
—— scavenging in, 217.
—— water supply of, 22, 227, 247.
Voelcker, Dr., F.R.S., charcoal as a deodoriser of sewer gas, 214.
—— value of sewage, 257.
—— value of sludge and night-soil manures, 268.

Wallace and Connell's water-waste preventer, 84.
—— waste-not tap, 238.
Wallasey, well in new red sandstone at, 114.
Waller's flush gate, 202.
—— manhole covers, 200.
—— penstocks, 203, 204.
—— self-acting balance valve gulley, 209.
Waring, Mr. (U.S.A.), sewer inclinations, 186.
—— ventilation, 215.
Warming of dwellings, rules for, 104.
Warner's lift and force pump, 137.
—— stand-pipe, 244.
—— steam engine, 136.
—— suction pump, 137.
—— wind engines, 132.
Warrington, pail system at, 221; Appendix I.
—— well in new red standstone at, 113.
Warwick, Earl, rent paid for Leamington sewage by, 257.
—— sewage applied by, on Heathcote Farm, 305.
Warwick, money results of sewage application, 260.
—— reduction of phthisis by drainage of soil at, 49.
—— treatment of sludge on sewage farm at, 267.
Washington (U.S.A.), rainfall at, 22.
Waste preventers and ball valves, 239.
Water Act of metropolis, regulations under, 232; Appendix M.
—— bearing strata, effect of rainfall in the replenishment of, 24.
—— capacity of different soils, 52.
—— closets and urinals, ventilation, trapping, and disconnection of pipes of, 67, 68, 71 150.
—— closet appliances, 71.

Water-closet towns and midden towns, sewage of compared, 252, 254.
Water, Division II.:
—— Sec. XVI. Constituents of normal water, 19.
—— XVII. Water, how polluted, 19.
—— XVIII. Quantity of water required for all purposes, 20.
—— XIX. Quantity and quality of water actually used in different towns in England, 22.
—— XX. Yearly and monthly rainfall, 22.
—— XXI. Infiltration of rain by absorbent soils in summer and winter, 25.
—— XXII. Quantity of rainfall evaporated or lost from absorbent and non-absorbent surfaces, 28.
—— XXIII. Quantity of rainfall thrown off pervious and impervious surfaces, 29.
—— XXIV. Waters classified according to source, 30.
—— XXV. Average composition of unpolluted waters, 32.
—— XXVI. Classified results of the chemical analyses of waters, 33.
—— XXVII. Wholesome waters, 34.
—— XXVIII. Suspicious waters, 34.
—— XXIX. Dangerous waters, 34.
—— XXX. The engineer's view of the question, 35.
—— XXXI. Of so-called "wholesome waters" — springs, 36.
—— XXXII. Of so-called "wholesome waters"—deep wells, 36.
—— XXXIII. Of so-called "wholesome waters"—waters collected from uncultivated surfaces, 38.
—— XXXIV. From whence is a supply to be obtained in districts where neither deep well waters, spring waters, nor waters from uncultivated lands are at command? 38.
—— Sec. XXXV. Of so-called "suspicious waters"—waters collected from roofs and impervious surfaces, 39.
—— XXXVI. Of so-called "suspicious waters"—the water of underdrainage, 43.
—— XXXVII. Of so-called "suspicious waters"—water from cultivated surfaces, 44.
—— XXXVIII. Of so-called "dangerous waters"—rivers, streams, and running waters, 44.
—— XXXIX. Of so-called "dangerous waters" — shallow well waters, 45.
—— XL. Of hard and soft water, 45.
—— XLI. Concluding remarks: Further investigation into the water question necessary, 46.
—— fittings, power of local authorities over, 231, 232, and Appendices J, K, L, M.
—— fittings, regulations of Manchester corporation as to, 232, and Appendix K.
—— means to be taken for prevention of waste of, 77 to 90, 232; Appendices J, K, L, M, N.
—— meters, 232, 233, 234.
—— necessity of constant service, 229.
—— power as a means of raising water, 133.
—— quantity of used in certain towns on intermittent and constant system, 22, 230.
—— rates in country places, 109, 246.
—— rates in different towns, 22.
—— supply commission, 29, 36, 38, 39, 44.
—— supply of dwellings, 21, 35 to 47, 108, 235.
—— supply of towns and villages, 21, 35 to 47, 227, 246.
—— tight sewers, necessity of, 13, 15, 51, 65, 150, 163, 164, 178, 182, 191, 192, 226, 247.
—— waste preventing arrangements, 77 to 90, 232 to 244.
—— wheel, 134.

Water Works Clauses Act, 231; Appendix L.
Watery vapour in air, 6.
—— quantity congenial to health, 7.
Watford, well in chalk at, 115, 116.
Way, Professor, lime process, 292.
Wealden formation as a source of water supply, 32, 118.
Weare and Co.'s, sewage process, 286.
Weight and cost of iron pipes, 197, 198.
Wells, Abyssinian tube, 119.
—— and tanks, motive power and machinery suitable for raising water from, 127.
—— construction of, 123.
—— cost of, 114 to 117.
—— deep, as a source of water supply, 34, 36, 111 to 118.
———— failure of, 36, 112; Appendix F.
———— lowering of water level in, 36, 37, 112; Appendix F and Diagram I., Appendix
———— objections to, 118.
———— quality of water from, 31, 33, 34, 36, 111.
—— distance of, from sewers, 247.
—— medium depth, effect of rainfall on, 110.
———— failure of, 110, 111.
—— pollution of, by middens and privies, 60, 219.
Wells, shallow, as a source of water supply, 31, 35, 45, 118.
Wet soils, as sites of dwellings, effect on health, 11 to 16, 18, 48 to 55.
Whitthread's sewage process, 284.
Wholesome waters, the chemists' view, 33.
—— engineers' view, 36.
Wicksteed, Mr., C.E., sewer velocities, 185.
Wind engines, 132.
—— power, as a means of raising water, 132.
Winds, their counteracting effect on air pollution, 7.
Witt, Professor, value of sewage, 256.
Wolverhampton, money results of sewage application at, 260.
Woollen and cotton mills, liquid refuse from, 168, 255.
—— mill, purification of liquid refuse from, 335.
Woolwich, well in chalk at, 115.
Worthing, reduction of phthisis by drainage of soil at, 49.
Wrexham, money results of sewage application at, 260.
—— rent paid for sewage farm at, 258.

York, monthly rainfall at, 23.
—— water supply of, 22.

THE END.

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